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GENERAL ELECTRIC REVIEW

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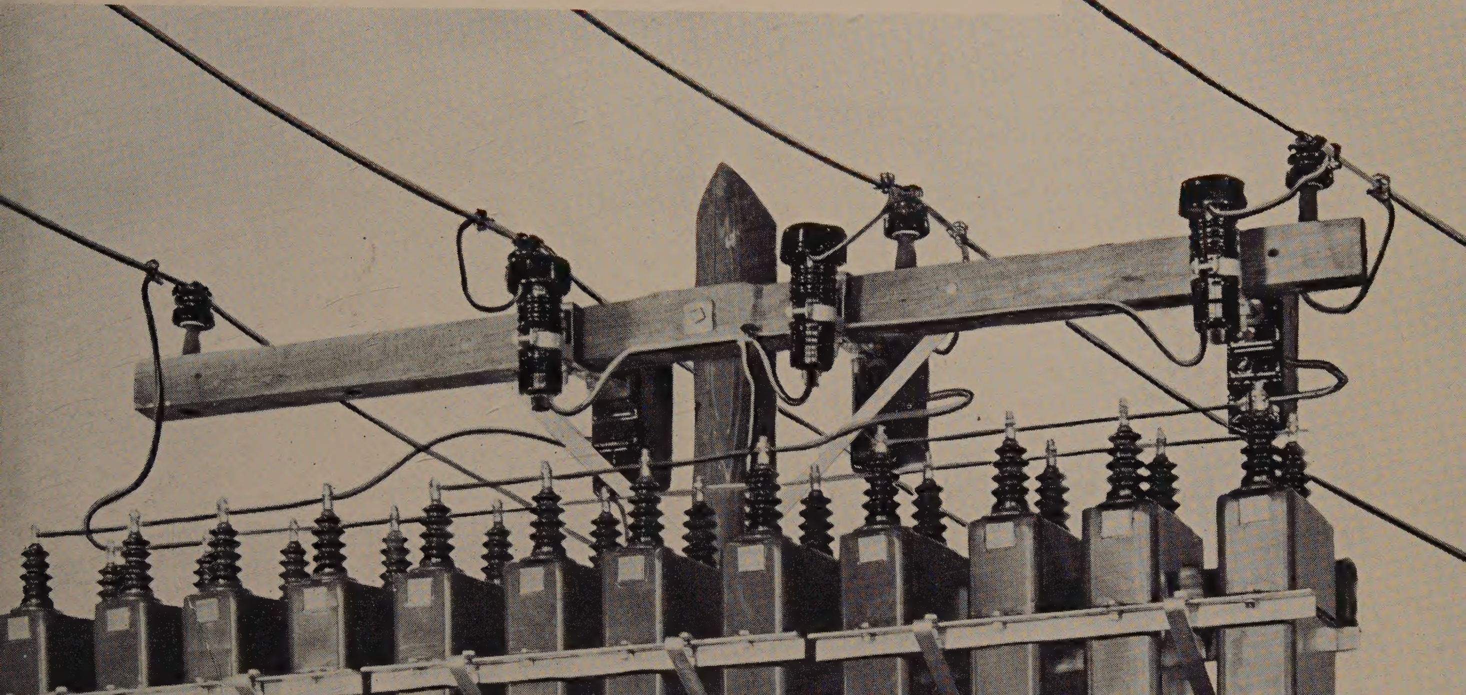

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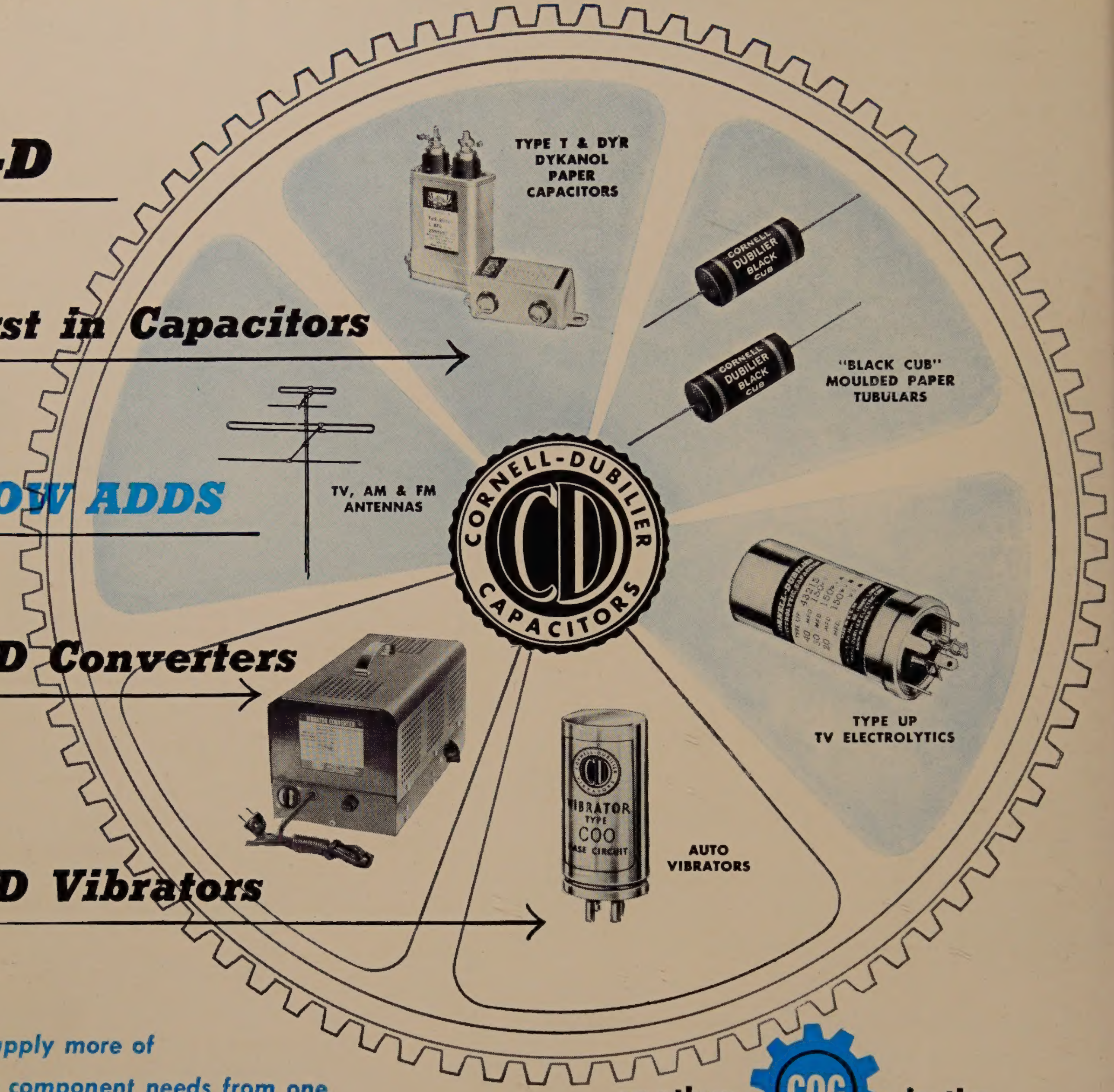

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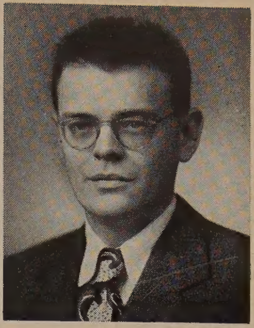
RADIOACTIVE TRACERS USED IN CORROSION STUDIES

Isotopes of common elements which participate in corrosion reactions, when made radioactive, can be followed through a series of chemical changes and combinations by the use of a photographic plate and a Geiger counter

By C. G. BACON

General Engineering and Consulting Laboratory
General Electric Company



Conrad G. Bacon

AMONG the newest tools of science are the radioactive tracers now available from the United States Atomic Energy Commission at Oak Ridge, Tennessee. These tracers are isotopes of common metals, and of some nonmetal elements, which have been made radioactive in an atomic chain-reacting pile. As chemical combination or physical state have no effect on their radioactivity, one can locate them easily in a chemical combination or follow them through a series of chemical changes. The photographic plate and the Geiger counter are the detection instruments used in determining their presence.

The first event leading up to the present situation occurred in Paris in 1896. Henri Becquerel had just received a few samples of uranium-bearing ore sent to him by a geologist friend in Czechoslovakia. Being engaged in other work, Becquerel put the ore away in one of his desk drawers, where he had previously stored some unexposed photographic plates tightly wrapped in black paper. Some days later, when he had occasion to develop the plates, he was puzzled by certain superimposed foggy outlines of a peculiar pattern. Investigation disclosed that the uranium ore had partially exposed the photographic plates despite the wrapping paper, which was opaque to light. Becquerel then took a sample of his ore, carefully polished one side of it, and clamped it to a photographic plate. Several days later he developed the plate and obtained the first real autoradiograph. Its appearance probably was very similar to the recent autoradiograph which is reproduced in FIG. 1.

All of this, however, did not lead immediately to the use of radioactive materials as tracers. Uranium and radium, the only radioactive materials available at that time, were not very frequently found as normal elements in the many chemical and physical combinations and processes which needed study. The radioactive-tracer method has its most significant value when the uncertain course of the element of interest in a particular reaction can be followed closely by making that element radioactive. The tracer art therefore remained undeveloped until a practical method of making a large number of susceptible elements radioactive became available. The atomic chain-reacting pile which came out of the second World War provided such a method.

RADIOACTIVE MATERIAL FOR LABORATORY TESTS

Practically all chemical elements can now be made radioactive and in considerable quantities. For instance, a one-hundred-gram lot of radioactive iron can now be obtained at a nominal cost. Chemical combinations and processes having iron or other elements as constituents can now be studied by substituting radioactive for normal iron and following the course of the element through the action with suitable radiation-detection methods. Similarly such reactions as take place in steel and gasoline refining, metallurgy, corrosion, and other processes may be studied in this manner.

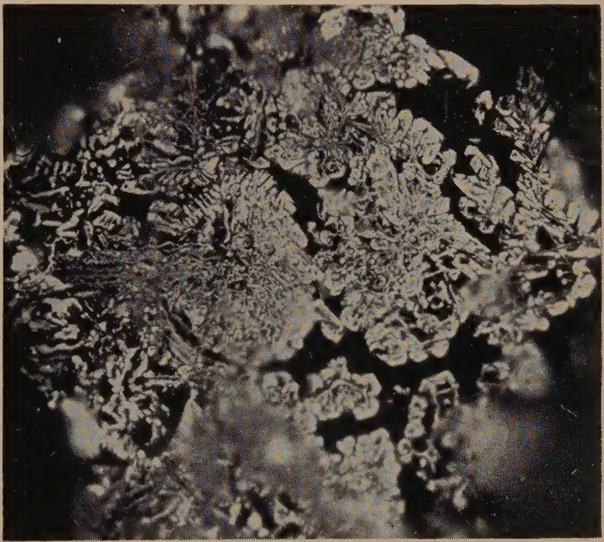


Fig. 1. Autoradiograph of a polished piece of uranium-bearing ore. The white areas indicate radioactive deposits in the ore

An attack on the problem of corrosion by the application of radioactive tracers obtained from Oak Ridge is being made in the General Engineering and Consulting Laboratory. Radioactive iron is used in an electroplating solution made up in the usual manner, and a polished test surface is then plated with a thin layer of the radio iron.

In taking an autoradiograph of the sample, the radio-iron-plated surface is laid on the emulsion side of a

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photographic plate. A plate-and-developer combination is used to obtain the maximum contrast. The plate is exposed for about three days, the exact length of time depending on the initial radioactivity and age of the iron isotopes being used.

The radioactive material used is a mixture of two iron isotopes—iron 59 and iron 55. The radioactivity of iron 59 decays to half of its initial value in 44 days; the half-life of iron 55 is 4.4 years. The activity due to the 44-day isotope is reduced to 1/256 of its original value after a period of one year. Since the tests described here were performed a year or more after the radioactive iron was received from Oak Ridge, the photographic action was due almost entirely to the 4.4-year iron. It has been found that reasonable activities are left a year after receipt of the bombarded iron, and that the 3-day exposure is sufficient.

THEORY OF THE PROCESS

To understand what is actually going on in such a process, imagine that a metal base, *A* in Fig. 2, is covered over, or plated, with radiomaterial *B*. A photographic plate *C* is clamped on to the active layer *B*, and the radiation from *B* will cause a reproduction of layer *B* to appear on photographic plate *C*.

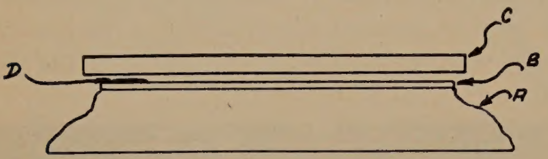

Fig. 2. Schematic diagram of components in the autoradiograph process as used in corrosion study:

A: metal base
B: radioactive plating
C: photographic plate
D: oxide formed where corrosion has been initiated

Now assuming that a spot of oxide is formed at *D*, where corrosion has been initiated, the iron—now being diluted with oxygen—has not the same degree of concentration as the original parent-metal surface of the surrounding area. There is thus a decrease in density of the developed plate area at this point.

The second factor that accounts for part of the process is that the layer of oxide at *D* begins to absorb the radiation arising from the underlying iron.

The third effect is the easiest of all to understand. Where the radioactive material has been completely removed from the area in question—removed by some solution process or by the formation of soluble salts and the consequent carrying away of the active material—a "dead" spot in the radioactivity remains.

In any event, if one of these three processes is initiated by any factor such as corrosion of the plating, an extremely interesting photograph of the removal process is at once obtained, photographed, as it were, by itself.

The procedure of using a very thin plating of the active material accounts for the successful result, because slight points of corrosion break completely through the radioactive layer and produce a high change in activity at the surface of the radioactive layer by even slight pitting of the iron surface.

For a series of radiographs, the original metal plate is used, just as it comes from the plating process, to obtain a reference photograph. The condition of the surface is carefully noted, as some defects are most certain to show at this point unless the plating job has been done perfectly. This step yields information as to the porosity of the plating, and, by careful survey, estimates of plate structure may be made. As experience is acquired in reading and handling this plating procedure, details of this nature become quite apparent and better understood.

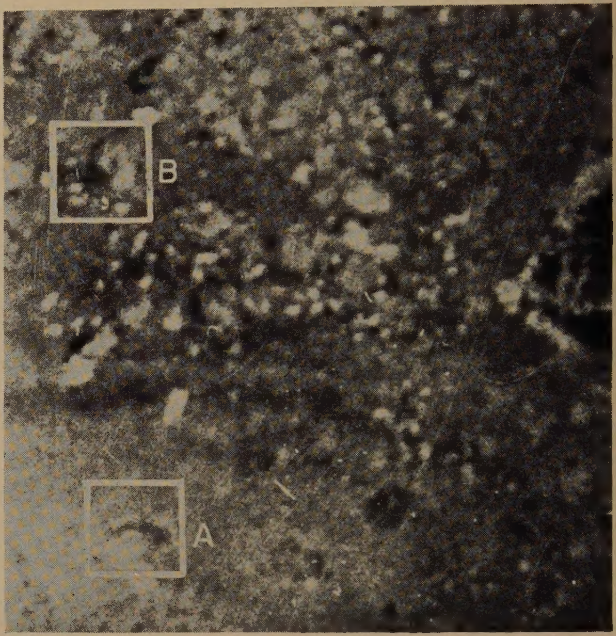

Fig. 3a. Photograph in normal light of a sample of iron plate (×3.5) after being corroded for 55 minutes

When a good original photograph has been obtained from the original plate, the sample is exposed to attack by corrosion. After the surface has been exposed to the corroding medium for a set length of time, the surface is blown dry by means of compressed air, care being taken that the surface is not marred. When the block is completely dry, it is placed in contact with a photographic plate for three days. Close contact by means of medium pressure is desirable to increase the clarity of the image. Upon development of the photographic plate one can see with good clarity the details of the corrosion process.

ANALYSIS OF THE DATA

Close examination and comparison of Fig. 3a, the normal light photograph, and Fig. 3b, the autoradiograph, shows the greater fidelity with which the radioactive iron can be located by the latter method.

The light photograph shows, in its mottled appearance, the different reflection characteristics of the constituents of the corrosive action. In such a photoraph, however, it has not been found possible to detect recisely the locations of those constituents.

In the autoradiograph, Fig. 3b, the lights and darks re very definitely outlined. The radioactive iron has een accurately recorded as to location; compare, for xample, the areas *A* and *B* outlined on the two photoraphs. The sharpness of the autoradiograph leaves no uestion as to the distribution of the iron in the light reas. The dark areas show a reduction of the iron in the ron oxide formed and the darkest areas indicate almost omplete absence of iron, due most likely to the disolving away of the iron in the form of soluble salts.

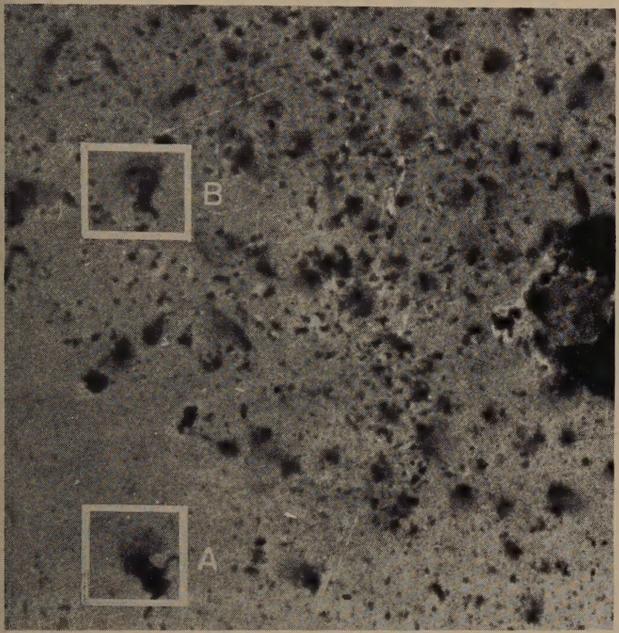

Fig. 3b. Autoradiograph of the same corroded sample of iron plate (X3.5) that was shown photographed in normal light in Fig. 3a

Similar conclusions cannot be drawn quickly from he light photograph. The tracer method, however, in he manner described, leads positively and quickly to efinite conclusions.

It is obvious that other corrosion phenomena can be tudied in this same manner by the use of other isotopes hich participate in corrosion reactions.

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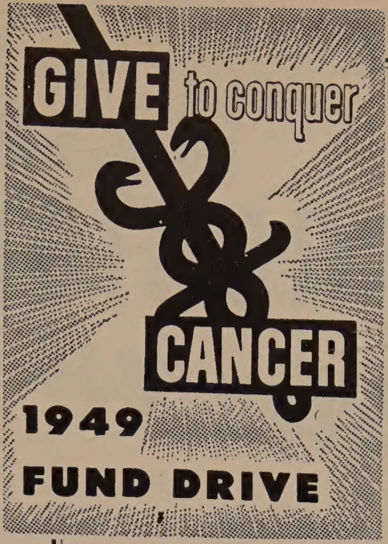

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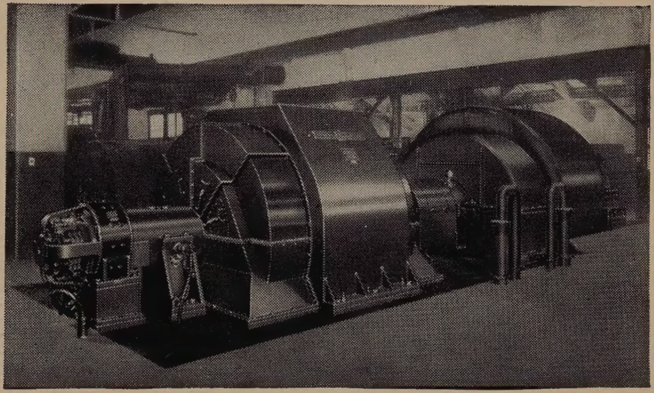

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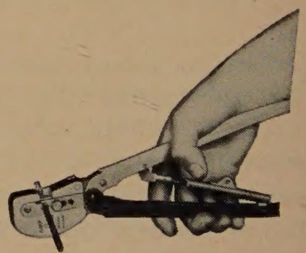

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TWENTY-FIVE YEARS OF PROGRESS IN TRACTION-MOTOR DESIGN

Advances are in accumulated small changes. Improved performance by increase in motor speed and numerous changes in electrical design. Standardization reduces first cost and upkeep

By M. J. BALDWIN
Motor Engineering Division, Erie Works
General Electric Company

MJ Baldwin

ALTHOUGH the traction motor at some 60 years of age is one of the oldest motors in electrical service, it is nevertheless a thriving oldster with an annual output of approximately 2.5 million horsepower, which in the past quarter of a century has gained new vigor from the rapid development of the diesel-electric locomotive.

This period has been marked also by the development of the P.C.C. standardized trolley car and the increasingly popular trolley coach, and by the application of 3000-volt trolley power to commuter-service multiple-unit cars and to new types of locomotives both here and abroad.

It is the purpose of this article to review the progress that has been made in traction-motor design, and to note the particular design changes that have contributed to the improvements made.

DESIGN OBJECTIVES

Traction motors are designed primarily for minimum weight. This is particularly true for trolley cars and coaches where weight is at a premium; and it is true also, to a somewhat lesser degree, for rapid transit. For diesel-electric locomotives, where so much vertical space is required by the engine, a small wheel size is also important. On trolley locomotives, additional weight in the motors usually would be permissible, where ballast is used, to obtain required weight on the locomotive drivers. Large heavy motors have been found, however, to add more to the cost of a locomotive than is saved in ballast.

Efficiency plays but a minor role in traction-motor design. Any increase in efficiency, if obtained at a cost of increased weight, tends in general to be offset by the added cost of hauling this extra weight around. Nevertheless there has been a decided gain in efficiency as speed and horsepower have increased.

COMPARING MOTORS—SPEED-RATIO POWER

Two factors are of primary importance in measuring the application capacity of a traction motor: (1) continuous rated horsepower and (2) the ratio of maximum permissible to rated speed. The first factor, rated horsepower, requires no comment since this is generally accepted as the primary if not the only measuring unit. The traction motor, however, must be rated at a relatively low speed; and it must also be capable of operating at maximum permissible speeds ranging from 2 to 5 times its rated speed. If variation in rotation losses with speed could be ignored, and if the ratio of mechanical to electrical material could be assumed to be a constant, a motor with a speed ratio of 5 would have 5 times the tractive effort and 5 times the size and weight of an equal hp purely hypothetical motor rating only at the maximum permissible speed. The product of these two factors, the ratio of maximum to rated speed × the rated horsepower, is here called "speed-ratio power" and is used to compare, in Figs. 1 to 7 inclusive, the advances made over the years in the various lines of motors. Gains range from 70 to 300 percent, depending upon the application.

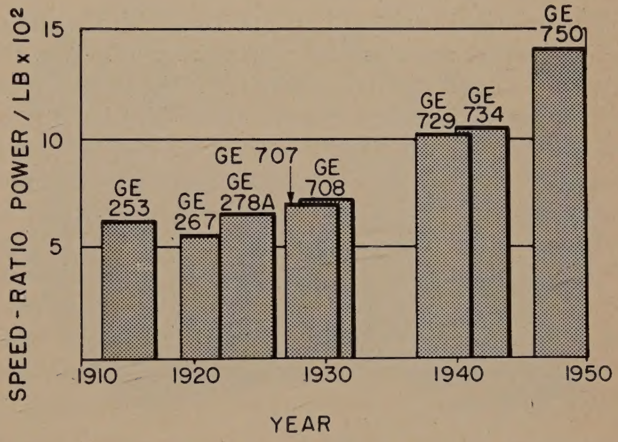

Fig. 1. Progress in design of 3000-volt locomotive motors as indicated by comparison of specific motor output shown in terms of speed-ratio power per pound of motor weight

Speed-ratio power is an accurate measure if used to compare motors that are not too widely apart in peripheral speed at the rating. In each case, the comparisons here made are for a given class of service, and the error due to differences in peripheral speed is estimated to be not over 5 percent.

SOURCES OF ADVANCEMENT

Advances in the design of a motor as old and established as the traction motor are arrived at generally in

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Presented as a paper at the AIEE Winter General Meeting in New York City, January 31 to February 4, 1949. The author wishes to thank his associates for assistance given him in the preparation of this paper.

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such small steps that it is not until the history over a relatively long period of time is reviewed, as has been done in the comparisons mentioned, that the over-all progress can be appreciated. The advances have been brought about by an accumulation of quite a number of seemingly small changes.

ROLLING-CONTACT ARMATURE BEARINGS

The first significant change that took place during the past 25 years was that from the waste-packed sleeve to the rolling-contact type of armature bearing. Compared to the sleeve type, any benefit that may have resulted from the reduction in friction due to the rolling-contact feature was incidental, although there is no doubt some slight reduction in torque requirement on an initial cold start. The rolling-contact bearing, however, does have three advantages over the sleeve: it operates at high speed with simple and reliable lubrication, it requires less axial space, allowing room for increased active material, and the negligible wear with which it operates makes possible better maintenance of gear centers.

The principal problem in connection with the use of rolling-contact armature bearings has been to keep the lubricant in and dirt and water out. The solution has been fairly well worked out for grease. Oil is an ideal lubricant for rolling-contact bearings and very little is required in the bearing at any time. Leakage and vaporization make it difficult to confine and means must be provided to continually replace that which is lost. Where oil is the gear lubricant, it is possible to obtain an adequate supply for the pinion-end bearing from the gear case. In this instance, however, general practice is followed in that the commutator-end bearing is grease lubricated.

GEARING

On large-size traction motors, at the beginning of this 25-year period, twin gearing usually was used. Two gears, pinions, and gear cases were required, one pinion being mounted on each end of the armature shaft, and one gear being mounted on the locomotive axle or wheel hub at each end of the motor. Equalization of gear loading was obtained by the use of springs between the rim and the center of each gear, tangential motion being permitted between the two parts in these "spring" or "cushion" type gears. About 20 years ago, twin gearing of this type was replaced by single gearing using solid gear, pinion, and gear cover. This change gained added space axially for active material in the motor core and effected an appreciable cost reduction.

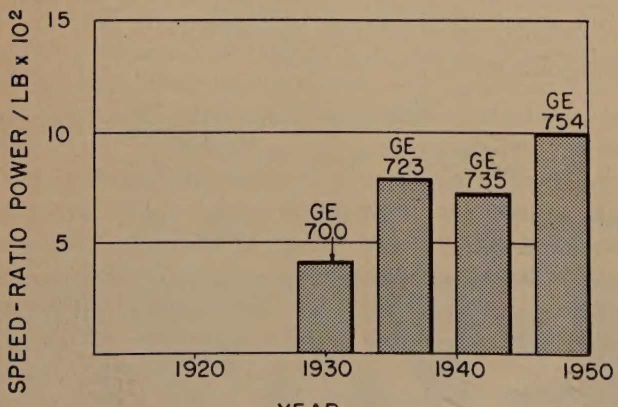

Fig. 2. Progress in design of 3000-volt multiple-unit car motors as shown by specific motor output compared as in Fig. 1

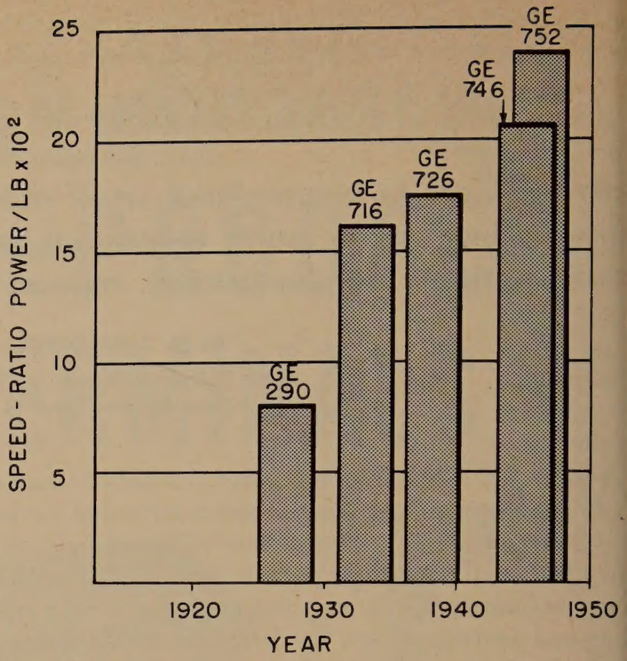

Fig. 3. Progress in specific motor output of internal-power road locomotives. A typical motor unit is shown in Fig. 3(a)

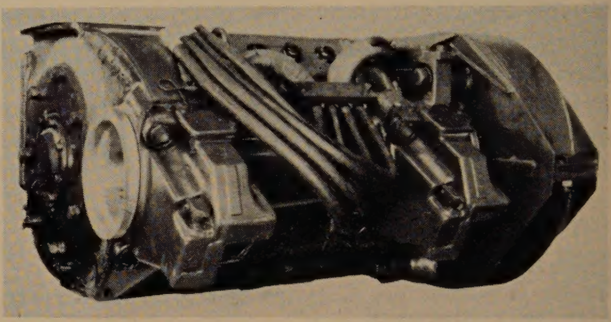

Fig. 3(a)

Elimination of the second set of gears was in part made possible as a result of the better gear-center-distance maintenance resulting from the use of rolling-contact armature bearings, as has been noted; but there also were improvements made in the fundamental design of the gears and pinions. The gearing of the older twin-geared motor was cut and heat treated, but left relatively soft to permit wear in service to equalize cutting variations in the teeth and the tooth spacing. With the development of equipment for grinding tooth profiles after heat treatment, a harder, stronger gear material was used. The pressure angle of the teeth was increased to obtain more strength in bending. The two small fillets and short tangential section connecting adjacent teeth were changed to a single long-radius fillet to minimize stress concentration in the pinion hub and gear rim. The grinding of the profiles improved the ivision of load on the teeth and minimized the torsional stresses in the armature shaft caused, particuarly at high speed, by variation in spacing of the teeth.

Another popular way of obtaining high gear reducion is by making the pinion integral with a short shaft supported by bearings adjacent to the pinion on both sides. This so-called "straddle-mounted" pinion can be made unusually small. Its use has been found practical where the gear unit is separate from the motor as is the ase for truck- or body-mounted motors used on P.C.C. ars, trolley coaches, and at least one of the most recent medium-sized traction motors.

OUBLE-REDUCTION MOTORS

In the past ten years, the double-reduction traction motor has come into widespread use for internally powered locomotives operated principally in switching service. Motors of the general type shown in Fig. 5(a) have two reductions; the high-speed is of the spur type, the low-speed being a hypoid. All bearings in the case, the pinion-end armature bearing, and also the axle linings are lubricated from the same oil bath. Only the commutator-end bearing of the motor is separately lubricated with grease.

TRUCK-MOUNTED OR BODY-MOUNTED MOTORS

On most of the small railway motors, such as the ones used on P.C.C. cars and trolley coaches, the axle-mounted motor has been abandoned in favor of a motor mounted on the truck frame or body of the vehicle. The connection between the motor and the gear box is of the double universal-joint type quite similar to the ones used on trucks and automobiles. Relatively high gear reductions are made possible in these automotive-type gear boxes. The corresponding increase in speed-ratio power per pound is indicated by comparing the older trolley-car motors, Fig. 7(a), with the P.C.C. car motors, Fig. 7(b).

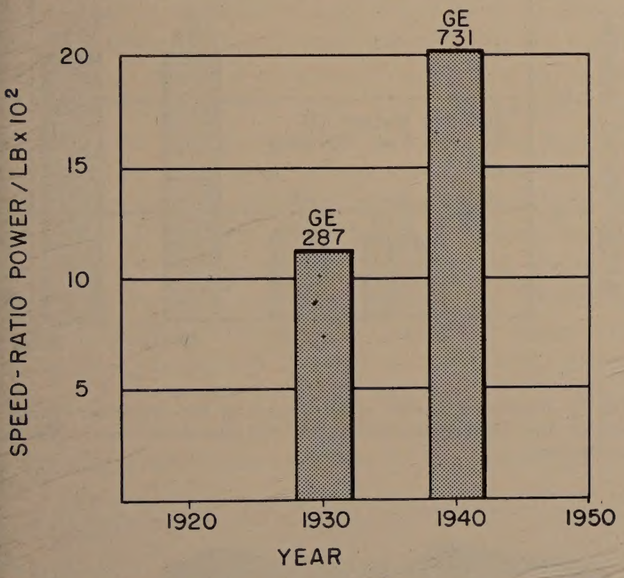

Fig. 4. Progress in specific output of internal-power heavy switching locomotive motors of the type shown in Fig. 4(a)

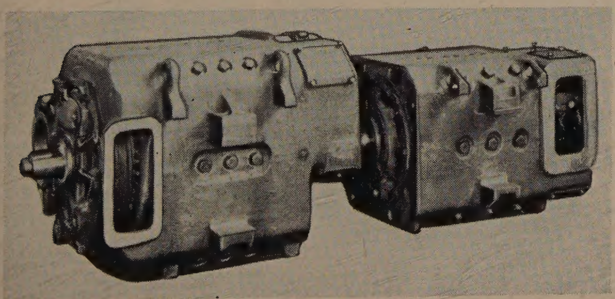

Fig. 4(a)

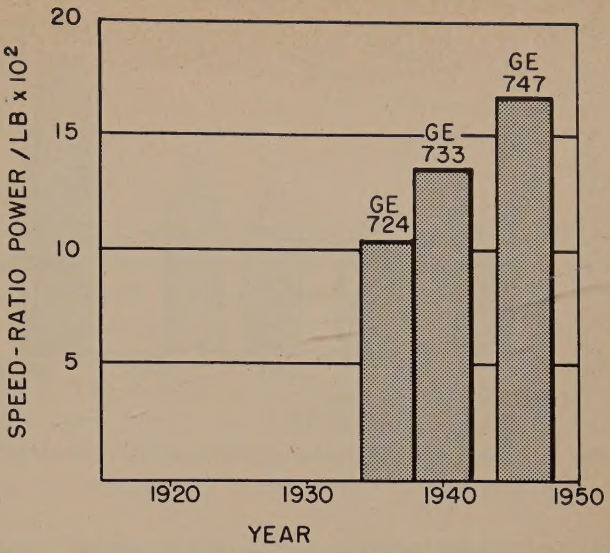

Fig. 5. Progress in specific output of internal-power light switching locomotive motors. The motor shown in Fig. 5(a) has double-reduction gearing

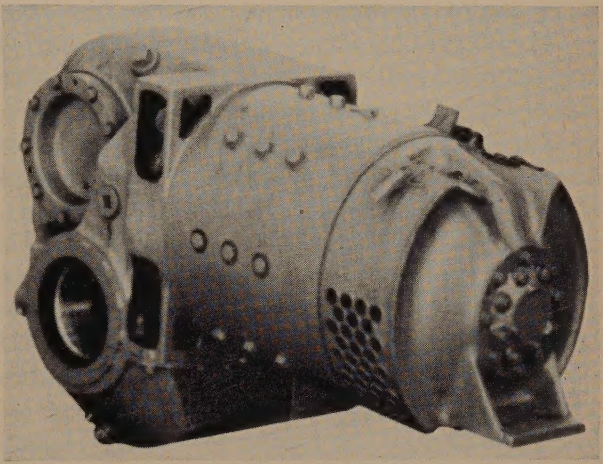

Fig. 5(a)

COMMUTATORS

Increases in armature speed have been made possible largely as a result of corresponding improvements in commutators. On all high-speed motors, particularly those used in road service, the commutators are spun. This is the word generally used to designate the curing process. It consists of an indeterminate number of cycles of heating while revolving at high speed, cooling, and tightening, which are repeated until a commutator surface is obtained that is smooth and relatively unaffected by variations in either speed or temperature.

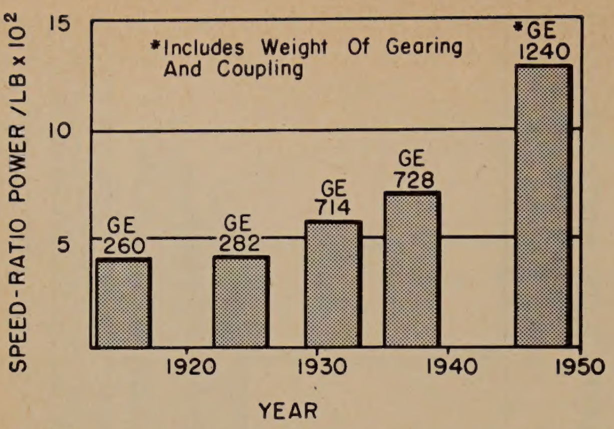

Fig. 6. Progress in specific motor output for 600-volt multiple-unit car motors

This process is expensive, but at present appears necessary to obtain commutators which are good for the maximum operating speed of approximately 10,000 ft per min currently used for most railway motors. Increasing use of commutator spinning has been made from about 1925, the details of the process being continually the subject of developmental work, seeking means of obtaining better commutators.

Instead of having the usual vee-bound commutator, a few of the most recent motors have been equipped with arch-bound commutators. These two types of commutator are essentially the same in appearance and construction. In the so called vee-bound type, the bars are clamped axially between the vee-shaped sections without developing high pressure between the bars. In the arch-bound type the retaining vee-shaped sections of the cap and shell are machined so as to serve only as retractors to draw the bars in toward the center of the commutator and thereby build up tangential or "arch" pressure between the segments. Of the two types, the arch-bound commutator generally has a somewhat better surface and requires less spinning.

BRUSHES

Along with improvements made in commutators there have been complementary improvements made in brushes. Brushes having a porous surface have been developed that tend to maintain contact in spite of minute variations in the surface of the commutator. During the past eight years, extensive use has been made of the split-type brush consisting of two parts, each half the thickness of the usual solid brush. Both the change in material and this splitting have resulted in the brushes' maintaining more intimate contact with the commutators, particularly at high speed, and have effected a marked improvement in commutation.

BINDING AND WEDGING

The windings of most armatures today are held in the core slots by means of wedges, whereas formerly magnetic steel binding wire was used. When nonmagnetic steel wire was developed, it was used where needed as a means of reducing cross-slot flux, thereby improving commutation; and also as a means of reducing band losses, thereby improving rating. With further increases in core speed and corresponding increases in the required amount of binding wire, it became necessary about 1930 to begin to use slot wedges in the core portion. This change eliminated banding loss in this region

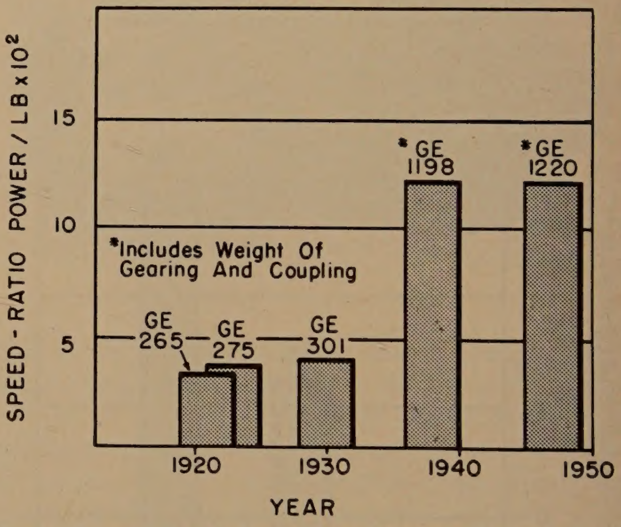

Fig. 7. Progress in specific motor output for 600-volt street railway motors. The older type is shown in Fig. 7(a); the P.C.C. type is shown in Fig. 7(b)

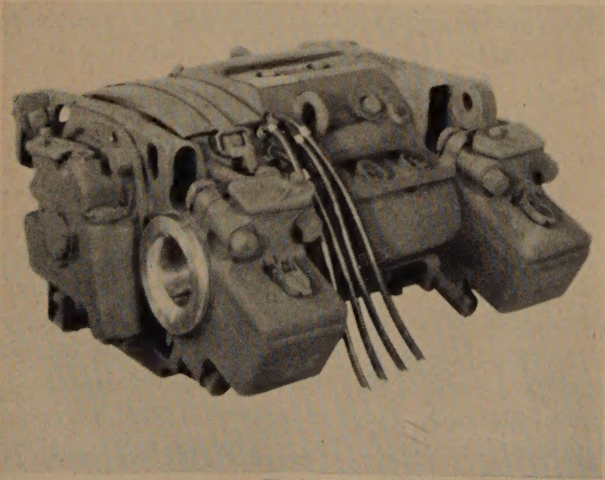

Fig. 7(a)

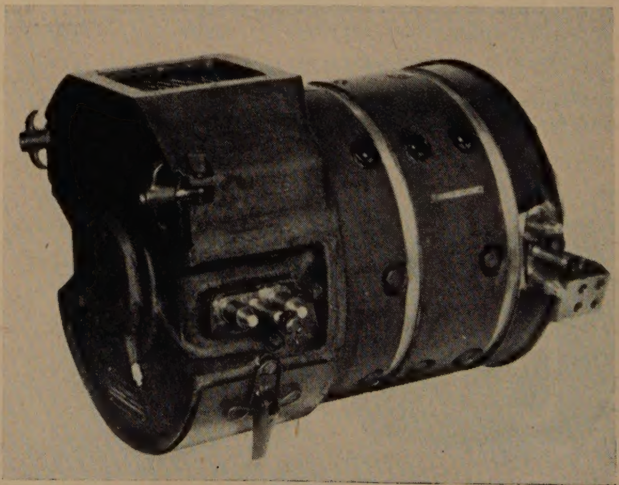

Fig. 7(b)

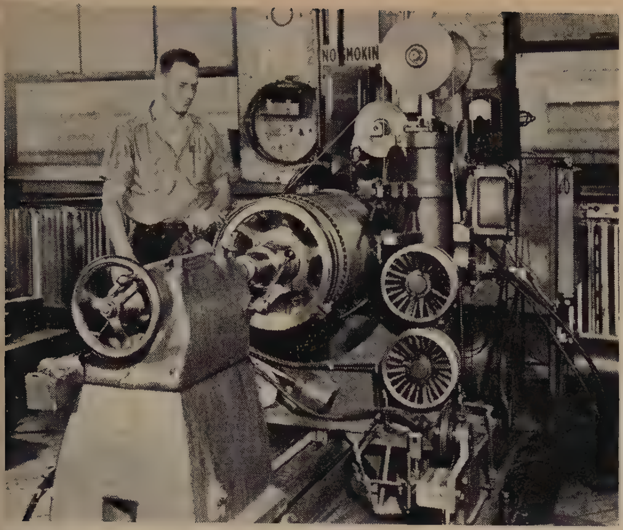

Fig. 8. The operation of re-roll binding is employed in the construction of higher-speed motors to produce a more compact structure

entirely and increased heat dissipation from the core teeth. Core speeds today are approaching 13,000 ft per min at the maximum permissible vehicle speed in service.

RE-ROLL BANDING

In order to bind the end windings down solidly, a relatively new practice termed "re-roll banding" has been established on some of the higher-speed motors. This operation consists of applying a layer of binding wire, anchoring it at both ends but running one strand over a pulley which is arranged to apply tension in this loop and to take up any slack. The wire is reeled over this pulley as the hot armature is rotated as shown in Fig. 8 and the high-tension loop travels backward and forward across the winding surface distributing the pressure to all portions of the winding. In the core portion, a steel bar is temporarily laid along the coil in the top of each slot during the binding process. These bars are free to move radially and are of such thickness that the binding pressure is applied to them and through them to the core portion of the winding. By means of the other turns of wire, the pressure is retained until no additional slack can be taken by the traveling loop.

VENTILATION

Ventilation has been increased on most traction motors, particularly the larger sizes which today are blown somewhat harder than was considered economical a few years ago. Early traction motors were made to rely more upon thermal capacity than those designed today. Some 30 years ago motors were series-ventilated, a practice which limited the amount of air to that which could be forced through the armature. Today practically all traction motors are multiple-ventilated, the air going through the machine in two parallel paths, one through the armature and the other through the air gap and between the stator coils. In motors insulated for 600 volts or less, the air velocity has been increased n the last 10 years from about 3000 ft per min to its present approximate value of 5000 ft per min. On the higher-voltage thicker-insulated motors it has not been found worth while to blow very hard because of the unaffected thermal resistance of this dielectric.

INSULATION

The size of a given motor is affected to a marked degree by the thickness of the insulation. Thick insulation not only reduces the amount of available space for copper or steel but also increases the resistance of the thermal path by which heat must escape from the copper. The problem is to obtain an insulation that is consistently good, that may be applied with normal shop handling without becoming damaged, and one that in service will stand Class B temperatures or higher.

Class A materials are not being used on modern traction motors. Mica has been and still is the basic Class B insulating material. Mica insulating tapes and sheets have been improved by the use of thinner retaining paper. This newly developed material is but one-half mil in thickness—approximately half the former thickness—but has adequate strength. As this paper is permitted only as a means of applying the mica, the less used the more nearly heat proof and more strictly Class B is the insulation. Increasing use is being made of glass-backed mica tape which completely eliminates Class A material from the insulation.

Glass outer protective insulation has largely supplanted asbestos. The glass has more per-unit tensile strength, making possible a tighter taping or wrapping of coils and also a saving in insulation space.

A change was introduced about eight years ago in the method of insulating commutating coils where fields may be connected in the circuit at approximately ground potential, and where the motor is for use on locomotives operating on internal power. The so-called "mummified" type of insulation, in which the coil turns are completely taped together, has been abandoned as being unnecessarily large and heavy for this particular kind of service. Instead, the first two or three turns, depending upon creepage needed, are taped separately with ground insulation providing full thickness on the end turns and tapering the insulation to provide fewer tapings on the inner turns. Center turns are left bare. The commutating pole is wrapped with insulation, the coil assembled on the pole, the entire unit impregnated in synthetic varnish, clamped on blocks to simulate assembly in machine and cured in an oven into a practically incompressible, hard unit.

Coils of the type just described are used on small locomotives, where only one connection of motors is required. On larger locomotive motors where two-motor combinations make necessary operation of field coils at more than ground potential, a similar coil is now being used mounted on a metal spool instead of directly on the pole. Here again this is done only for use on locomotives operating from internal power. Permafil, a new synthetic thermosetting varnish, is used for mica insulation bonding and final impregnation. Center turns on these coils are individually glass-taped. These coils are air-cured, clamped in a mold, and heat-treated into an essentially incompressible, hard unit which, however, differs from the smaller coils in that the commutating pole is removable. The design is indicated in FIG. 9. The coils are held in place on the pole by means of multiple-leaf nonmagnetic spring pole tips.

REDUCTION IN USE OF CASTINGS

The past quarter century has seen much of the work that was once done in the foundry transferred to the fabricating and welding shop. Only in the largest-size magnet frames are castings more generally used than fabricated structures. Wherever possible, frames have been changed from octagonal to round and formed by rolling at a reduction in cost. Where space limitations require a rectangular or octagonal shape of frame, the cost is marginal and the change to fabrication may or may not prove economical.

Fabrication of stators using punched sections welded together have been made on a trial basis. FIG. 10 shows how this type of frame appears after welding and before machining, and also the appearance of a completed motor. These machines have operated successfully in severest subway service for 15 years. This construction offers some advantages, particularly where electrical transients are severe.

While fabrication is used or not used largely on a cost basis, both the rolled-plate and punched fabrication offer a more uniform flux-carrying medium than castings in which unseen blow holes and porosity may occur.

Commutator shells and caps are now generally made from forgings instead of castings wherever the quantity involved is so great that this construction proves most economical. Frameheads are being "hogged" more and more from ordinary heavy welding plate instead of being made from castings.

ELECTRICAL DESIGN

Although not so apparent, a number of changes in electrical design have been made during the past few years. Many of the more recent motors have made use of the twisted-lead type of armature winding (FIG. 11) instead of the solid, deep bar, the stranded-wire type (FIG. 12), or the transposed bar types (FIGS. 13 and 14). The twisted-lead type of armature coil offers high slot-space efficiency combined with low eddy-current loss, both effecting increases in armature capacity. The cost of the twisted-lead type is also lower than that of the transposed-bar types. It is on the motors with three or more coils per slot that the twisted-lead type of coil offers a gain in combined space efficiency and low loss as compared to coils of the other types. The more coils per slot, the more the gain on both counts, making this type of coil most useful in higher-voltage motors—particularly those for 3000-volt trolley operation.

While resulting in a reduction in heating and increase in rating, the use of a shallow conductor increases the problem of obtaining a suitable adjustment of compensation to meet the requirements of all coils in a given slot. The eddy currents of the deep conductor tend to equalize the rate of change of current in the several coils during commutation, and also tend to cause some of the energy of commutation to appear as heat rather than sparking. The proper balancing of commutation difficulties against heat reduction is always a problem in any shallow conductor winding when it is used where commutation is inherently difficult.

Windings of the bar type have been used for many years in coils in which the back pitch is not a multiple of the coils per slot. Coils of this type are usually brazed at the end opposite the commutator, necessitating a removable flange and special molded flange insulation, all tending to make this type of coil expensive. There is, however, a definite gain in reduced commutator maintenance when this type of back-pitching is used as compared to that in similar motors where the coil back pitch is a multiple of the coils per slot. In order to take

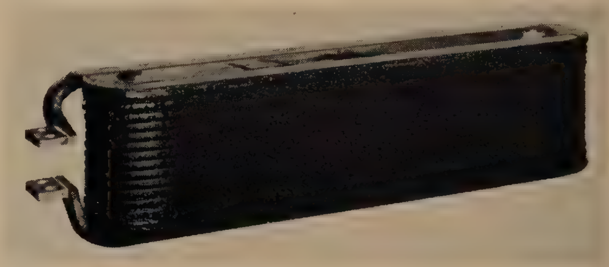

Fig. 9. Commutating-field coil for a motor used on internal-power locomotives

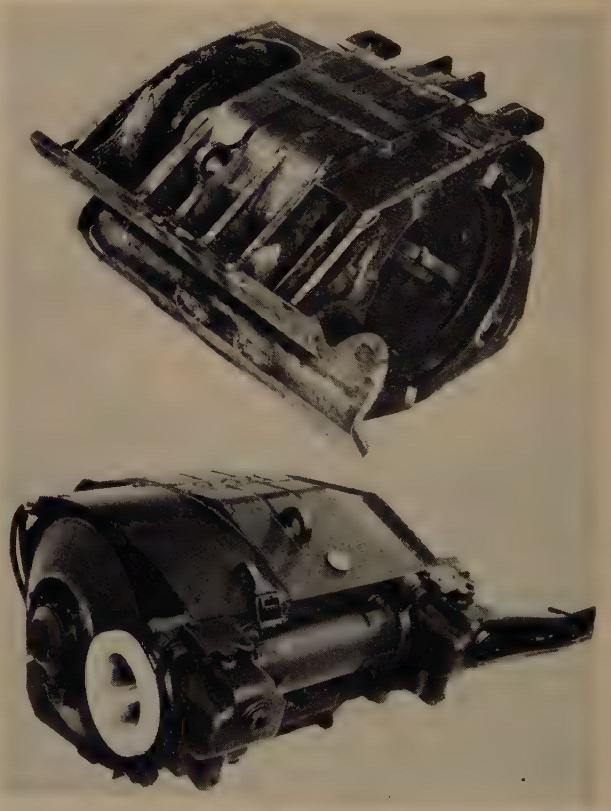

Fig. 10. Traction motor with frame fabricated from punched shapes by welding

advantage of the twisted-lead coil and still use the special back-pitching of the bar-type coil, many motors now use a modified form of this twisted-lead type of coil which is ordinarily known as the "orphan coil." The design of this type of coil is indicated in Fig. 15. Such windings have slot-space efficiency comparable to that of the bar types and are somewhat less expensive in over-all armature cost.

About 1930, it was found advantageous to increase the amount of iron and decrease the amount of copper compared to the ratios previously used. The optimum proportion insofar as the armature is concerned has been found to be about two parts of iron to one part of copper in the effective circumference of the armature. This proportion works out well on motors having more than four poles. On four-pole motors, it has generally been found advantageous to use a little higher percentage of copper to avoid excessive flux density in the armature core beneath the teeth.

In order to reduce peak voltage between adjacent commutator bars, caused by flux distortion, it has been found desirable to increase the air gap from a minimum value at the main pole center to a maximum at the tips. Gaps flared in this way, in addition to reducing flux distortion, also tend to limit losses in the tips due to pulsation in flux caused by the passing of the armature teeth.

STANDARDIZATION

In the last 20 years, much progress has been made toward the adoption of standard machines in all lines of traction motors. The adoption of a standard trolley-car motor as a result of co-operative developmental effort on the part of the car operators put this type of vehicle in competition with the gasoline coach. Similar co-operation between the operators and the manufacturers has resulted in the idea of a standard motor being carried over into the trolley-bus application.

In the field of trolley locomotives, the manufacturers are attempting as much standardization of motors as the several gages of track and variations in trolley voltage will permit. Designs in this field, however, are still largely determined by the customer through limiting specifications, although every effort is being made by the manufacturers in this country to adopt standards. Where complete motors are not standard, certain parts are being used as far as possible on different applications.

The internal-power locomotive offers the best possible opportunity for standardization on a widely applicable motor for several different weights of locomotive. The GE747 motor shown in Fig. 5(a) is used on 25, 45, 50, 65, and 80-ton locomotives. Different numbers of motors per locomotive and different gear reductions are used depending on the maximum speed desired, which ranges from 25 to 50 mph. This motor is made to be applicable on any track gage down to 36 in. minimum.

For road locomotives of 50,000 lb per axle or over, each manufacturer appears to have adopted a standard motor. Generators are designed to fit the motor since there is less than half the cost in the generator that there is in the motors of a four-motor locomotive. Not only is there a greater percentage of the equipment cost in motors than in generators, but there is also a larger number of smaller units. Both of these considerations favor motor rather than generator standardization.

It is of interest to note that the motor for internally powered locomotives is being reduced in size to a point where wheel diameter, instead of being determined by

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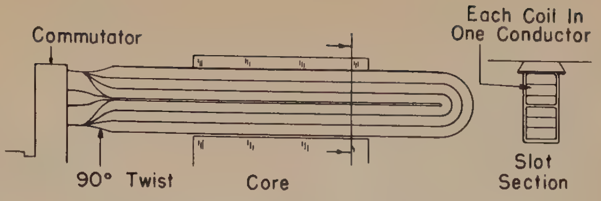

Fig. 11. Twisted-lead armature coil

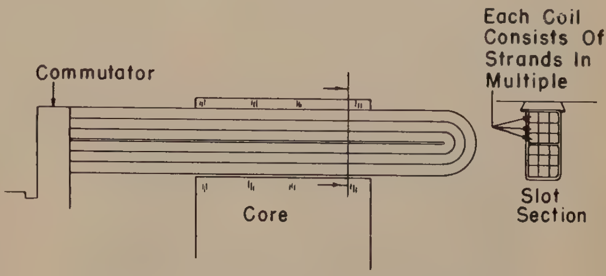

Fig. 12. Conventional stranded-conductor armature coil

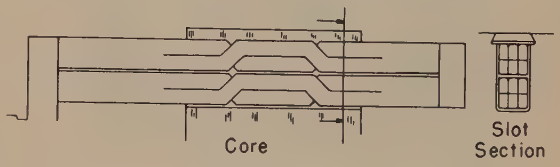

Fig. 13. Double-cross-over bar armature winding

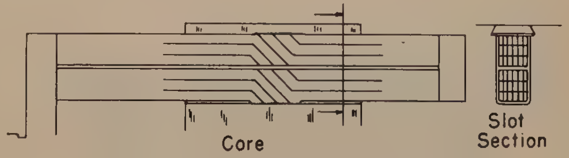

Fig. 14. Folded-bar armature winding

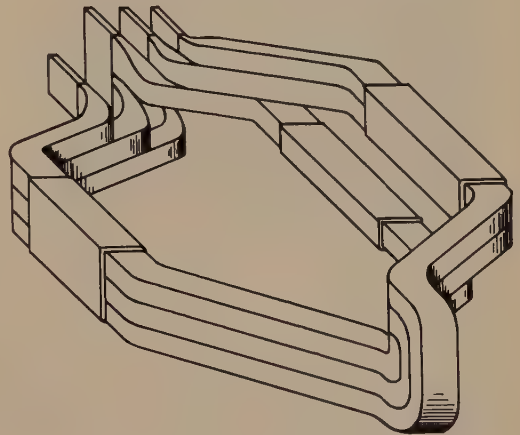

Fig. 15. Orphan-type armature coil

NOTICE
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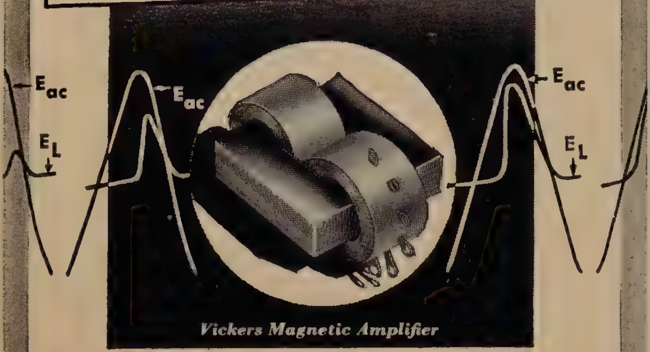

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E-2

TRACTION-MOTOR DESIGN

(Continued from preceding page)

motor size, is now in some cases on the heavier road locomotives being determined by the weight on the driver—that is, by the per-square-inch pressure on the rail. This situation is new and is welcomed as a possible aid to motor standardization. If the wheel rather than the motor does become limiting, a greater freedom is allowed in the choice of gearing for a small motor; or, conversely, the way is opened for a more universal motor not requiring specialized gearing.

Standardization tends to reduce first cost and makes better, faster servicing possible, particularly where the volume is sufficient to make unit exchange possible.

MAINTENANCE: UNIT EXCHANGE

The railway motor of today, like the automobile of today, is more complex—much more of a precision tool—and inherently more difficult to maintain than was the lower-speed motor of 20 or 30 years ago. As in the automobile service shop, the problem of keeping the traction-motor service shop fully informed regarding improved factory methods is one that is being solved by specialized training of service personnel supplemented by factory instruction sheets. The improved processes for binding, balancing, and spinning armatures, and improved equipment for handling and testing are being used in the service shop as well as in the factory to insure uniformly good operation from new and from rebuilt equipment.

Little of the increased maintenance problem is apparent to the operating railroad which uses standardized motors where unit exchange is available. Under the unit-exchange system, the operator turns in a motor needing service and receives, with essentially no delay, a rebuilt motor in exchange. This method of handling service is one of the most important results of standardization which is not possible with custom-built apparatus. The system of unit exchange spreads the cost of specialized servicing equipment over many users of a given motor.

CONCLUSION

The principal way in which power per pound has been increased during the past 25 years has been by means of increases in speed. Considering the limitations imposed by available known materials—fundamentally copper, steel and mica—this increasing of speed has proved to be the only way to accomplish progress in traction-motor design. Much work is currently being done developing new synthetic insulating materials which may one day clear the way to increased specific output. Higher than Class B temperatures are also being advocated for railway work. Further speed increases are to be expected despite increasing mechanical problems involved. The curves of output per pound are continually showing increase. The interesting problem presented to the engineer is to see that they continue to do so in the future.

THE WHY OF A 25-KVAR CAPACITOR

Economic considerations in manufacture and application of capacitors have demonstrated highly desirable features of the new units now used in modern capacitor installations

By M. E. SCOVILLE
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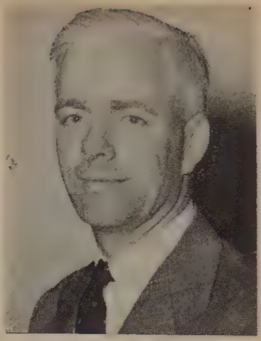


M. E. Scoville

THE 25-kvar capacitor unit, recently developed and introduced into commercial use, marks an historical advance in the art of capacitor manufacture. Familiarity with the peculiar nature of capacitors aids very much in appreciating the importance of stepping up to a 25-kvar unit rating after the 15-kvar rating has been the maximum unit standard for more than 15 years. This article gives the reasons for selecting a 25-kvar unit rating, along with supporting developmental history and related design factors; it also presents those operating characteristics that are most important to the user.

REDUCTION OF CAPACITOR PRICES EXPANDS USE

Capacitor unit development is very closely related to the economics of capacitor application in relation to other methods of supplying kilovars needed on a power system. It is essential to understand that drastically lower prices for capacitors for power-factor improvement have been a prerequisite to their widening application. More recently, price increase on many lines of electrical equipment has caused a widening spread in prices in favor of capacitors.

Power systems have been, and some still are, operated without the benefit of high-power-factor loads on their transmission and generating equipment. But in many systems with well-planned operating efficiency, higher and higher power factors are being maintained. There is an increasing trend by system engineers to make careful economic studies of their systems; and the conclusions reached almost invariably indicate that capacitors as kvar generators become an economic necessity. Both prices and number of installations have taken important trends as shown in Fig. 1.

The downward trend of installed costs for capacitors compared to recent upward trends for most other power system equipment makes capacitor economics astonishingly attractive. The large number of capacitors being installed annually is on a sound economic basis and the trend is expected to continue.

HOW COSTS HAVE BEEN DECREASED

More than 80 percent reduction in the price of capacitor kvars in 10- and 15-kvar sizes, accomplished in 17 years, has been the result of both intensive research in materials and utilization of quantity production methods. The introduction of Pyranol, a high-dielectric-constant synthetic treating liquid, initiated a new era. Pyranol gave the designer three very important advantages: 50 percent more kvar per unit volume; a more tangible means of assuring high quality; and long-time stability under what is considered high stress in other types of electrical apparatus. Capacitor unit designs were perfected to use the new material efficiently and effectively. As production quantities grew, labor-saving methods and machinery contributed to the downward cost trend.

Materials

First to be considered are the component materials, an important factor in the cost of capacitor units and basic in the design of the device. The principal materials used—kraft paper 0.0003 in. to 0.0006 in. thick, aluminum foil 0.00025 in. thick, the impregnating Pyranol, and other lesser items—are highly specialized and refined. These are produced in large quantities for capacitors only; and further cost reductions do not result from increased usage or larger sizes which might

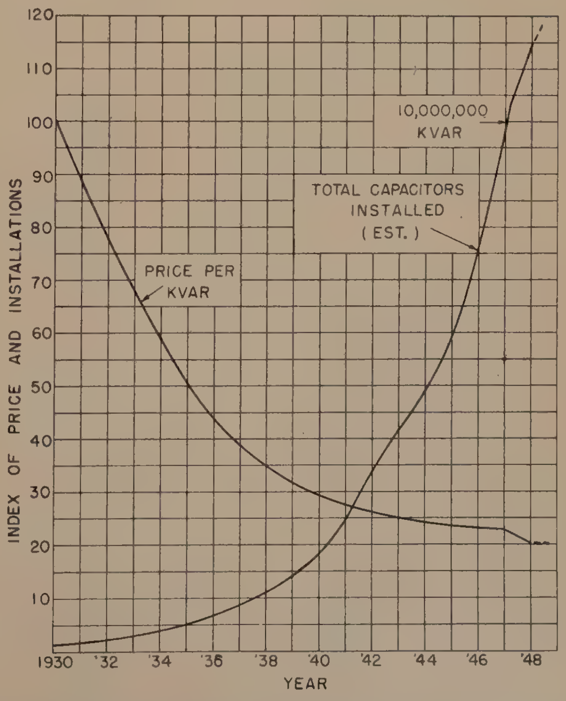


Fig. 1. Curves showing the price reduction on individual 2400-volt capacitor units during years since the introduction of Pyranol, and the total estimated United States installations including earlier oil-treated capacitors for power-factor improvement at all voltages. (Small capacitors sold as part of motors or fluorescent ballasts are not included.)

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

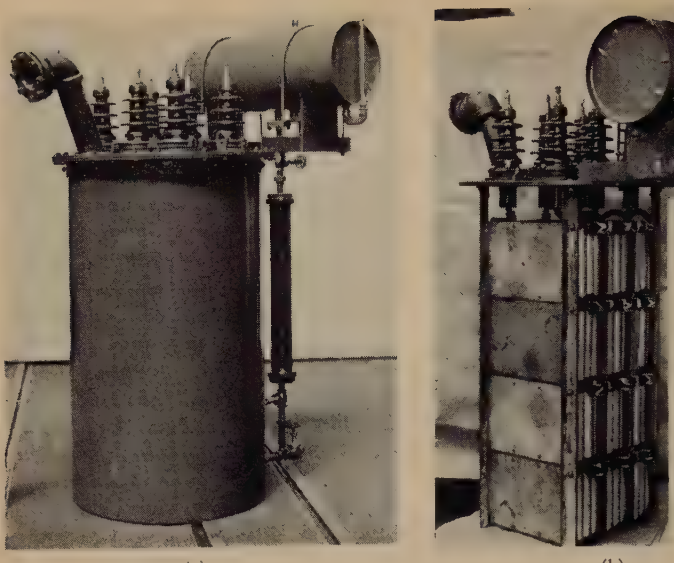


Fig. 2. A 200-kvar 21,000-volt 3-phase mineral-oil treated tank-type capacitor built as a developmental unit in 1928. After passing laboratory tests, it was connected to a utility system and operated satisfactorily for several years.

Fig. 2 (a) shows the tank, which was completely filled with oil and hermetically sealed, hence the need for the conservator
Fig. 2 (b) shows the internal assembly, consisting of a stack of 36 large flattened rolls supported on a wooden rack and connected twelve in series, three groups in delta

be possible in higher unit kvar ratings. These materials represent more than 75 percent of the cost of a capacitor and are essentially constant per kvar, regardless of unit kvar rating. An increased kvar rating above 15 kvar can be obtained only by adding more pounds of paper, foil, Pyranol, and steel in more than direct proportion to the rating increase to provide sufficient factors of safety in loss dissipation, dielectric, and mechanical strength. Labor content in the cost is low; therefore, the cost per kvar is affected only a small percentage by change in unit kvar rating. Thus, capacitors do not conform to the common idea that the larger the rating of a machine, the lower is the cost per unit rating, a principle which is well known for equipment such as generators, transformers, and motors. Therefore, unless improvements and cost reductions can be made in the major materials and combined with large-quantity production, only minor effects on price per kvar can be obtained by increasing individual unit sizes upward from 25-kvar.

The use of deep-drawn container parts helps to obtain low-cost construction, but places a practical limit on maximum size and depth. Units much larger than 25-kvar would require heavier-gage case material to provide the required rigidity and thus would make drawn parts less economical. The cost per kvar for container and inside insulation liners does not vary appreciably with container size in the range of 10- to 25-kvar unit ratings. Some items, such as entrance bushings, discharge resistors, connection straps, nameplates, paint, etc., required for each unit, show reduced cost per kvar for larger unit sizes, but the amount in relation to the total material cost is very small.

Ratings

The number of different individual unit kvar ratings manufactured has a definite effect on costs. Experience has shown that ratings in steps of about 10 kvar are desired at least in small quantities. If 10 kvar were the maximum rating manufactured, then only variations in design for voltage, phase, frequency, and physical dimensions would be necessary. Increasing unit kvar ratings to higher values multiplies the number of intermediate ratings which must be made. A large variety would handicap mass-production methods, leading to increased costs. A sufficient flexibility in bank kvar ratings is necessary to meet circuit requirements, but it is also important in the over-all return on capacitor installation investment to have a minimum number of ratings which are to be ordered, stocked, installed, and maintained. A 25-kvar unit rating appears to provide sufficient flexibility for larger bank ratings, and 10- or 15-kvar ratings meets the need for smaller ratings.

Maintenance

Another factor often neglected in considering return on the investment is replacement and maintenance costs, which must be included when large enough to effect real increases in the investment. Currently, this factor is negligible because capacitor designers have established dielectric voltage stresses and temperature limits which allow conservative factors of safety against failures in service. However, they know from experience that a small percentage of failures in the dielectric due to indeterminate causes must be expected. In fact, well-established service records for typical areas and types of

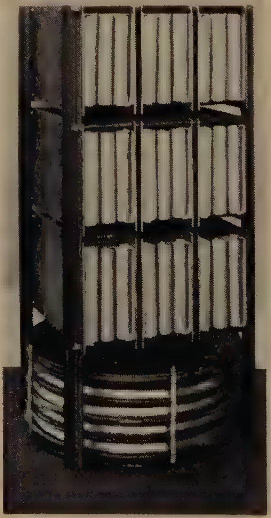


Fig. 3. Internal assembly of tank-type oil-treated capacitor rated 60 kvar 13,200 volts, single phase. Twenty-seven flattened rolls were mounted on an insulating rack. A compressible gas chamber at the bottom was included to allow for oil expansion within the hermetically sealed tank. Electrical connections between roll assemblies are not shown

installations have shown a low figure of less than one capacitor unit failure per year in a 15,000 kvar bank.

Slight reposition, in service, of the capacitor dielectric assembly due to expansion and contraction of dissimilar materials during thermal cycles and due to mechanical stresses is believed to be the cause of these indeterminate failures, which are impractical to eliminate by good quality materials and careful factory testing. If the unit kvar rating were increased several times, then the percentage of units lost will be increased likewise and so would the percentage of kvar lost for a given size bank installation. The practice by some manufacturers in this country 20 years ago, even on 5- and 10-kvar capacitors, was to use internal fuses on small sections to allow for failures without loss of a whole individual unit. This was done primarily because of quality of materials available. This practice still continues in Europe with mineral oil impregnation in which the arcing of a fuse in the liquid does not excessively deteriorate the characteristics of the liquid. The General Electric goal in capacitor design from the beginning has been to improve materials, processes, and testing so that, with the operating voltage stresses adopted, the number of indeterminant dielectric failures is low.

VERY LARGE UNITS HAVE NOT PROVED TO BE PRACTICAL

Even before the introduction of Pyranol, capacitor engineers had done considerable testing of large-unit kvar ratings. Over 20 years ago, a 200-kvar 21,000-volt 3-phase tank-type unit was built for test and trial operation on a utility system. Exterior and interior of this unit are shown in Fig. 2 (a) and (b). Another large developmental unit in tank-type construction was a 60-kvar 13,200-volt capacitor as shown in Fig. 3. This unit included a pressure reservoir in the bottom to allow complete filling and hermetic sealing without the necessity of an external oil reservoir. Somewhat later ideas were embodied as in Fig. 4 (a) and (b) in a 100-kvar 4600-volt 2-phase tank-type capacitor, which was placed in service at the factory. Thus much was learned about the manufacture and operation of large units. Cost studies showed this type of unit to be high in cost per kvar.

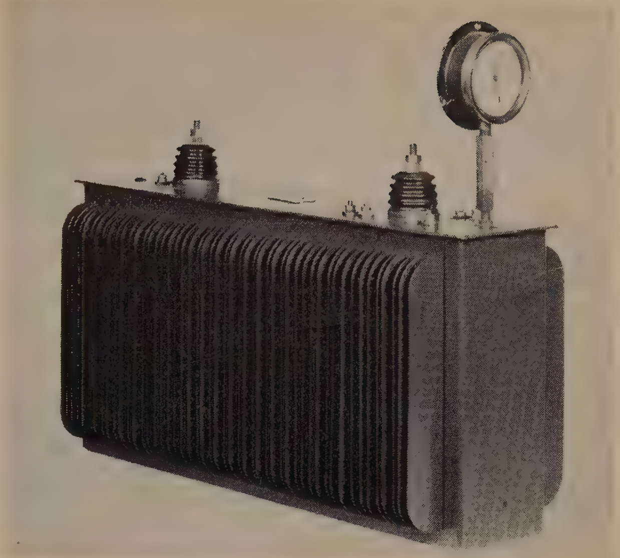
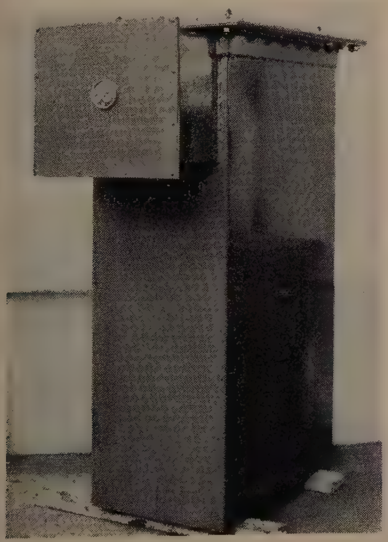


Fig. 5. This developmental capacitor unit, rated 50 kvar, 2400 volts, single phase, was built in 1936 using Pyranol and kraft paper in an all-welded container. Sufficient extra cooling surface to maintain the desired internal operating temperature was obtained with fins. The internal assembly differed from that of recent 25-kvar ratings only in size and the number of rolls. The small terminals are internal thermocouple terminations, used for recording internal operating temperatures. The pressure gage was used for measuring internal pressures due to liquid expansion in the completely filled container. Laboratory tests made to establish characteristics and heat-run life tests proved the design to operate with satisfactory temperature rise, consistent with expected good stability of dielectric materials during many years of continuous operation in service

The introduction of Pyranol presented a new base on which to build experience and establish design factors. The 10-kvar mineral-oil-treated standard rating changed to 15 kvar with Pryanol. The importance of heat dissipation and limitations on operating temperature to insure stability with years in service was established. Variations in design, such as extended foils internally, fins on the surface, and forced cooling were developed and tested to establish economic relationships. Subsequently, numerous Pyranol treated units rated 26 to 109 kvar, 2300 volts, had been built in various designs and tested to destruction. Typical of these is a 50-kvar 2400-volt single-phase 60-cycle unit shown in Fig. 5. Economic studies of a range of unit



(a)

Fig. 4. A 100-kvar 4600-volt 2-phase tank-type capacitor unit built in 1929 for tests and factory installation. This unit failed after several months of satisfactory operation

Fig. 4 (a) shows the rectangular tank, which conserved free oil and allowed for some expansion of the liquid with temperature changes. Service connections were made through the throat and tank wall bushings covered by a removable plate. Fig. 4 (b) shows the internal assembly of the capacitor which consisted of 18 large flattened rolls connected three in series, six in parallel in each of two phases

(b)

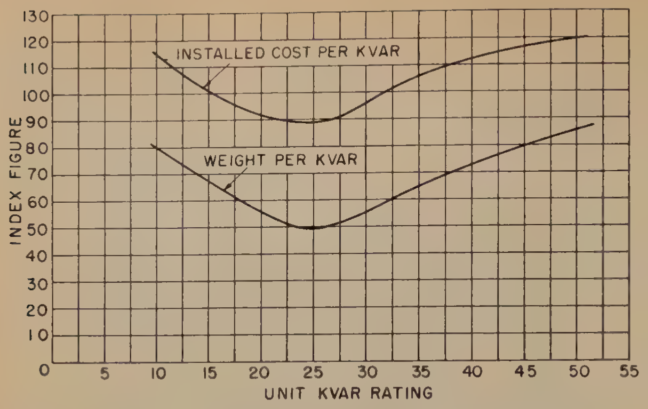


Fig. 6. Variation of installed cost and weight with increasing individual unit kvar ratings for 2400-volt Pyranol treated pole-mounted capacitors. (These curves are based on assumptions that production quantities of each maximum rating and those of lower value to provide flexibility in 10-kvar steps would be sufficient to utilize high-production methods and tools.)

ratings showed minimum cost for the 15-kva rating having balanced electrical and thermal characteristics without external fins. These studies also indicated a need for paper with lower dielectric losses to permit more economical construction for higher kvar ratings. The 15-kvar rating continued as standard more than 15 years.

A 25-KVAR RATING PROVES MOST ECONOMICAL

After five years of intensive research and development of capacitor paper, a much improved paper was placed in production in 1942. Use of the new paper in wartime production of capacitors accurately established the high degree of service performance all-important for a step up to 25-kvar ratings. Improvements in foils, treating, processing, and testing of materials all added up in the 25-kvar rating to give very good overall characteristics. The stage was set in 1947 for an upward step in capacitor ratings. An important consideration is the economic relationship which is shown in Fig. 6 by curves of installed cost versus unit kvar rating.

In working out designs for ratings above 25 kvar, it was assumed as a basis for economic comparison that some increase in dielectric thickness is necessary to provide adequate factor of safety against indeterminate failures. A twenty percent increase in dielectric thickness over that for the 25-kvar rating has been selected for a 50-kvar rating as a conservative assumption. Ratings above 25 kvar require fins on the case sides to aid in loss dissipation, thereby limiting the internal temperature rise to a safe value, even with the low-loss paper. Both the increased volume of dielectric materials per kvar required and the finned case construction contribute to the higher installed cost per kvar.

The variation in weight with unit kvar rating follows the same trend as installed costs, also shown in Fig. 6. It is important to note that the improved dielectric materials and container construction of drawn parts for the 25-kvar unit permit a low weight of 65–70 lb. This weight can be lifted by a single worker in the factory and at the point of installation. Packaged weights which are readily handled without mechanized lifting equipment, not available in many handling operations, tends to lower the handling costs. Banks up to 10,000-kvar, or even larger, may be built up at the installation location, using these most economical 25-kvar building blocks.

CONSTRUCTION OF THE 25-KVAR UNIT

The most important consideration in construction of the 25-kvar unit from both the user's and the designer's viewpoints is that all features are identical to those of the 15-kvar unit which have proved excellent during the past 10 years. Mounting dimensions in pole-type hangers are interchangeable with 15-kvar ratings. Mounting supports are the same, allowing easy installation with two bolts for each unit. Actual changes in design include increased paper and foil widths, larger drawn-case parts, larger case insulation parts, and lower values of discharge resistance. Figs. 7(a) and 7(b) show cutaway sectional views of the 15- and 25-kvar units respectively.

The sheets of aluminum foil and high-grade kraft paper tissue are wound into rolls and flattened. The rolls are then assembled into a pack of 12 or more and connected in parallel or series-parallel arrangements, depending on the unit voltage rating. Discharge resistors of the solid-carbon type are connected across the roll pack and the whole assembled in a molded kraft-fibre insulating box with overlapping joints, providing excellent major insulation to case. The two

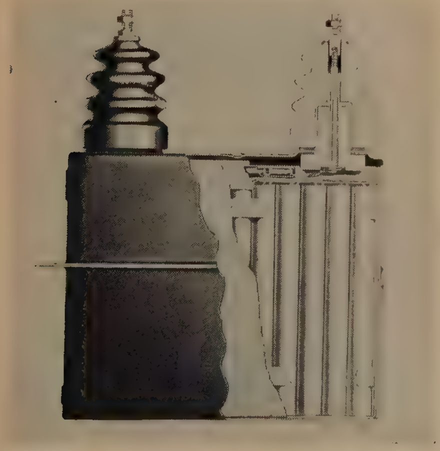
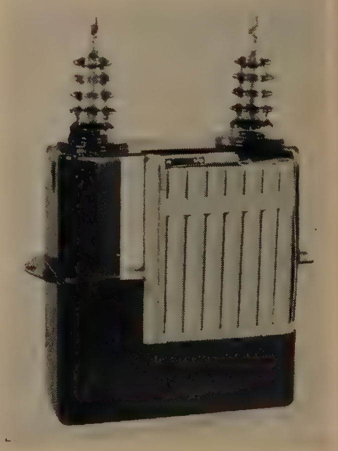

(a)

Fig. 7. Construction of Pyranol treated capacitor units

Fig. 7 (a) shows a cutaway section drawing of a capacitor rated 15 kvar, 2400 volts, single phase, 60 cycles

Fig. 7 (b) illustrates an outdoor pole-type capacitor unit rated 25 kvar, 2400 volts, sectioned to show interior elements


(b)

halves of the drawn-steel case are drawn over the assembly with a snug fit, both to minimize excess space for free Pyranol and to facilitate the dissipation of losses through the insulation to the container surface. After complete assembly and resistance welding of the case halves together, the unit is ready for drying, Pyranol impregnation, and sealing. Moisture in the paper is removed with heat and vacuum before admitting Pyranol, in a carefully controlled process, which physically and chemically transforms the capacitor dielectric between foils into a very stable, uniformly high-strength insulation.

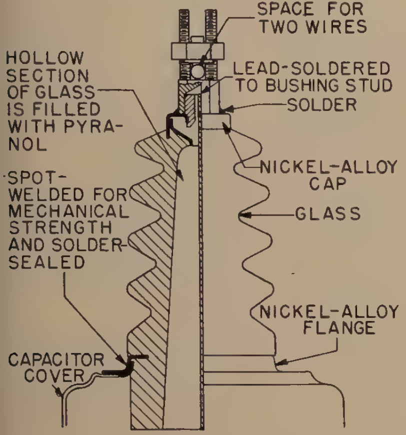

SPACE FOR TWO WIRES
HOLLOW SECTION OF GLASS IS FILLED WITH PYRANOL
LEAD-SOLDERED TO BUSHING STUD
SOLDER
NICKEL-ALLOY CAP
SPOT-WELDED FOR MECHANICAL STRENGTH AND SOLDER SEALED
GLASS
NICKEL-ALLOY FLANGE
CAPACITOR COVER

Fig. 8. Partial cross section drawing of a 5-kv cast-glass capacitor terminal bushing, showing the nickel-steel parts sealed in the body of the glass and solderless connector attached

The cast-glass terminal bushings that are used are a unique development. Molten glass is poured into a mold containing the metal cap and mounting flange parts and then allowed to cool, forming an assembly with co-ordinated expansion coefficients. The bushing flange is spot-welded for strength, and then soldered to the case cover, making a terminal seal without the use of organic materials. This seal has proved to be unaffected by the usual weathering and atmospheric conditions. A cross-section view of a 5-kv cast-glass bushing assembly is shown in Fig. 8.

OPERATING CHARACTERISTICS

The operating characteristics of a capacitor can be best understood after a careful study of internal losses and temperature effects. Though the losses in a capacitor are extremely low in terms of watts, it is extremely important from the designer's viewpoint to give thorough consideration to loss dissipation. Two important factors contribute to this seemingly inconsistent conclusion. First, the good thermal insulating qualities of a capacitor dielectric assembly and insulation to case makes even a very small internal loss cause a higher temperature rise above the surrounding ambient than might be supposed. Secondly, the maximum operating temperature of capacitor dielectric must be limited to lower values than those commonly considered safe for most electrical apparatus. This is true because capacitors operate at comparatively high electrical stresses and continuously at full-load temperature, since they do not operate at the usual low load factors common with most other electrical apparatus. The limit on internal operating temperature must be set by the designer, consistent with the materials he uses. He must rely on life-test data and experience with capacitors in service to establish a safe temperature limit. Short-time tests and accelerated life tests are reliable only for comparative purposes in establishing designs and materials.

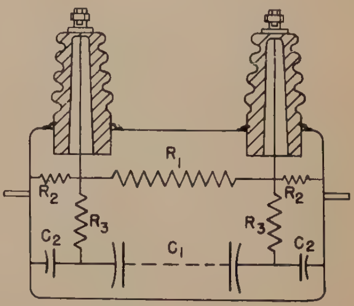


Fig. 9. Schematic diagram of 25-kvar single-phase 60-cycle two-bushing capacitor, showing internal electrical circuit elements as lumped values, excluding dielectric losses and internal inductance

C_1 = Terminal-to-terminal capacitance varying with voltage and kvar. (See table below)
C_2 = Terminals-to-case capacitance of 0.002 μf ±10 percent for all voltage ratings
R_1 = Terminal-to-terminal resistance, which is the value of the carbon discharge resistor varying with voltage and kvar (See table below)
R_2 = Terminals-to-case leakage resistance, including terminal bushing surface leakage resistance
R_3 = Terminal-to-terminal series resistance of conductors controlled by design to negligible values

Kvar	Rated Volts	Amperes	Capacitance (C_1) μf	Discharge Res. (R_1) Megohms	Terminal-to-Terminal Impedance Ohms at 60 cycles
15	2400	6.25	6.9	7.5	384
25	2400	10.4	11.5	3.75	231
25	4160	6.0	3.85	3.75	692
25	4800	5.2	2.88	15.0	921
25	7200	3.47	1.28	20.0	2075
25	7960	3.14	1.05	25.0	2570
15	7960	1.88	0.63	60.0	4230

Losses

The watts loss in a typical 25-kvar 2400-volt 60-cycle capacitor unit operating at rating may be allocated as follows (refer to Fig. 9 for a schematic diagram of internal circuit constants):

(a). Dielectric loss resulting in heating of the dielectric is a fixed characteristic of the materials used and about 97 percent of the total. The development of a lower-loss paper(1), in combination with Pyranol, has given about 25 percent reduction in dielectric losses, allowing the designer more latitude in design to improve operating characteristics and to reduce cost of cooling details.

(b). Resistance loss R_1 in discharge resistors is small, but is fixed by the allowable discharge time established as safe practice by the NEC Code and NEMA Standards 45–100 (five minutes to discharge to 50 volts for capacitors rated above 600 volts).

(c). Resistance loss R_3 due to current flow through the metallic conductors and through the dielectric is very small—less than one percent of the total. The metallic losses can be economically controlled to low values by increasing conductor sizes and making

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(1) "A New Kraft Capacitor Paper," by R. J. Hopkins and H. F. Miller, General Electric Review, December 1947, p. 20

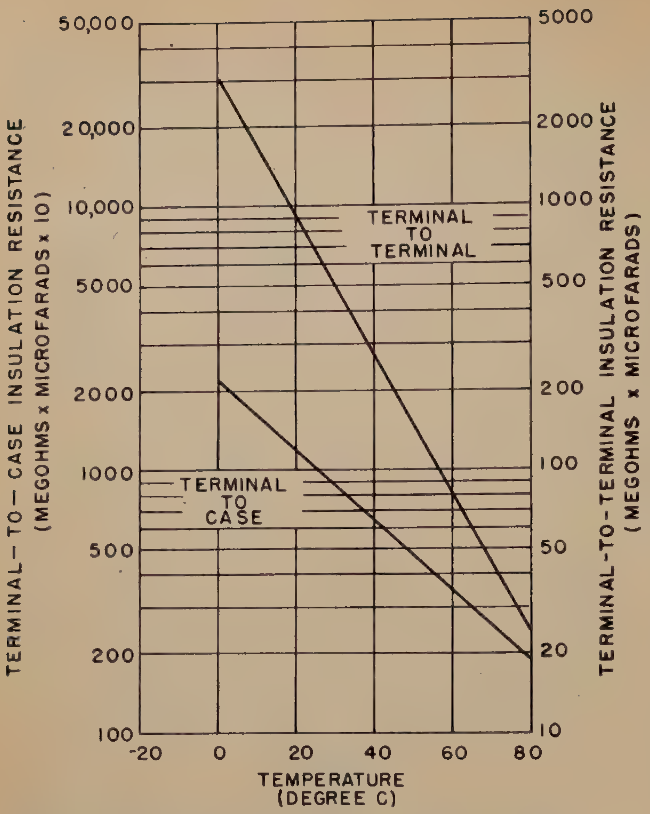


Fig. 10. Typical insulation resistance at various temperatures for Pyranol treated power capacitors

low-resistance joints. The insulation resistance to current flow through the dielectric material must be very high to attain other desirable qualities such as stability and voltage strength. Measurement of insulation resistance is of value only as a quality control and can be made only in special units without the discharge resistor connected. A typical variation of terminal-to-terminal resistance with temperature is shown in Fig. 10.

For purposes of measurement, the various losses can usually be lumped together as terminal-to-terminal measurement. Measurements should be made at rated voltage to eliminate the low voltage stress effect. An elaborate bridge set-up is required for such measurements, because of the extremely small watt loss value relative to the kvar rating. Such a bridge is required even for production testing. Only capacitor manufacturers and well equipped laboratories can usually afford these elaborate bridges to satisfactorily make such loss-measurement tests. Fig. 11 (a) shows a typical total-loss characteristic as affected by variations in uniform internal temperature of an unenergized unit, or under no-load conditions. However, during operation after a warming-up period, the actual temperature throughout a capacitor unit is not uniform, so that losses under operating conditions present a different relation, as shown by the "continuous" load curve in Fig. 11 (a).

Temperature Changes

Capacitor units are manufactured to a tolerance of 0 to +15 percent capacitance at 25 C, with the average above nominal. The variation in capacitance with uniform temperature is shown by the no-load curve in Fig. 11 (b). The sharp reduction in capacitance below −5 C (25 F) is due to change in viscosity of the Pyranol which congeals into a semisolid. In the congealing temperature range, the losses are much higher than in the normal operating temperature range as was shown by the no-load curve in Fig. 11 (a). Because of the higher losses, the capacitor will not operate with a stable internal temperature below the congealing range. If energized while at low temperature, the capacitance will continue to increase as the dielectric warms up and within a few minutes the dielectric assumes stable operation at a temperature above the congealing range.

Typical of such operation is the characteristic shown in Fig. 12 (a), assuming a capacitor is uniformly cooled to the low temperature and then energized at rated kvar and allowed to warm up. If a capacitor is continuously energized and the ambient temperature reduced, typical of actual service conditions, the internal operating temperature does not follow the ambient trend because of increased losses at the congealing-temperature range. Therefore, while the capacitor is in operation, the Pyranol is kept heated above the congealing range, regardless of operating ambient. The heat storage capacity or specific heat coefficient in a capacitor unit is relatively high. When operating in the dielectric temperature range where losses are low, as in the normal ambient range of 25–50 C, the time to reach a stable operating temperature is comparatively long, as shown in Fig. 12 (b). Obviously, a capacitor can be overloaded within allowable limits without fast change in operating temperature because operating temperatures lag behind changes in operating conditions by several hours.

For convenience, the unit's maximum internal operating temperature rise above ambient can be considered

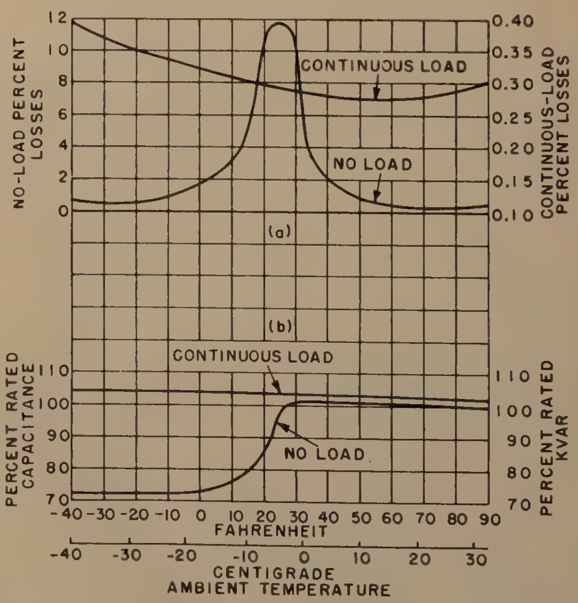


Fig. 11. Typical variations of (a) losses and (b) capacitance with ambient temperature for Pyranol capacitors under conditions of no-load and continuous load

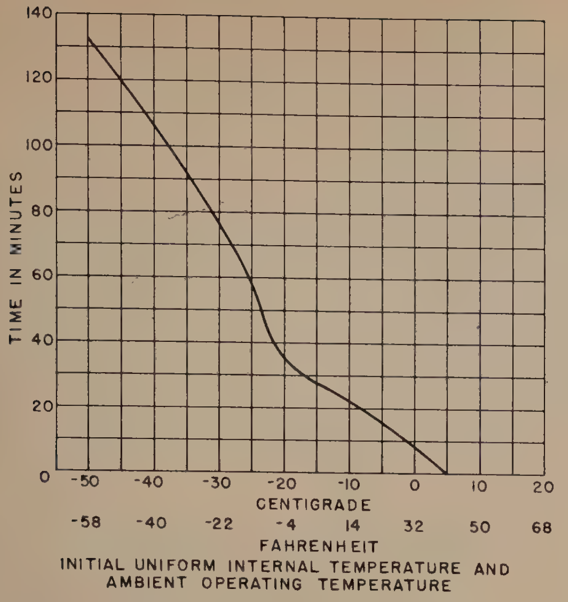


Fig. 12 (a). Curve showing the time required to warm up a 25-kvar 2400-volt capacitor unit after cooling to low ambient temperature values while unenergized, operated at normal voltage and frequency in an ambient equal to internal temperature at the start of operation

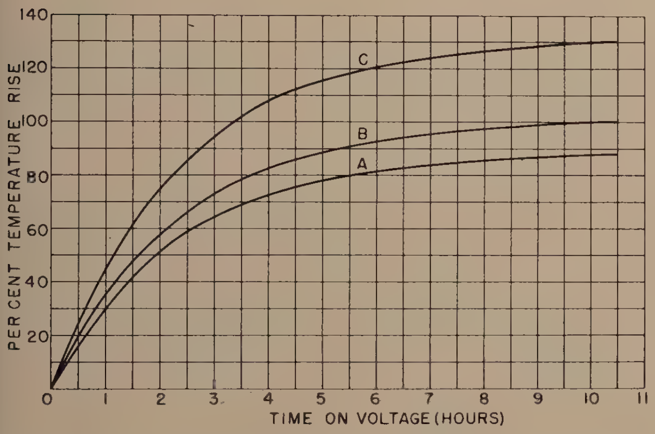


Fig. 12 (b). Curves of maximum internal operating temperature rise versus hours on voltage for typical 2400-volt 25-kvar 60-cycle outdoor pole-mounted capacitors in bright sunlight and 40 C ambient

Curve *A:* 100 percent kvar operation of an isolated unit

Curve *B:* 100 percent kvar operation of several units in a row with 4½ in. spacing between cases

Curve *C:* 135 percent kvar operation of several units in a row with 4½ in. spacing between cases

in two stages: First, the external surface of the container operates with a rise above ambient which can be readily measured in service; second, the internal dielectric operates with a temperature rise above case surface, which rise cannot be measured in service nor can it be controlled by the user. Therefore, to limit and control internal operating temperature to safe values consistent with the expected life in service, the capacitor designer must specify the operating and ambient conditions under which the operation will be satisfactory. Such conditions include ambient temperature, exposure to radiation from the sun or other apparatus, ventilating air temperature, and physical arrangement in banks.

Loss Dissipation

Normally, about half the loss dissipation from the surface of a capacitor unit is by direct radiation to surroundings, while the other half is carried away by natural circulation of air. Retarding either factor increases the container temperature rise, and improvement in either factor reduces the rise. Therefore, if radiation is reduced, then circulation of air must be increased to maintain a given case temperature rise. If air temperatures are high, then forced circulation will decrease the rise. When practical limits of natural or forced circulation are reached, further limitation in temperature rise may be obtained by reducing kvar rating, thereby reducing the watts loss to be dissipated per unit area of surface.

When a number of units are mounted in a row side by side and/or enclosed by surrounding walls, then the radiation factor is reduced. Fig. 13 shows such a typical relationship for spacing between 15-kvar units. The spread between curves is somewhat greater for 25-kvar units. If rows of units are mounted one over another, then air from a lower tier is heated before passing into the upper tier. A second and third tier of 25-kvar units may show 5C and 9C more temperature rise than a bottom tier in a typical indoor installation with unrestricted natural air circulation.

The 25-kvar unit has a somewhat higher case-surface temperature rise than the 15-kvar unit. Therefore, arrangements in bank assemblies should not be made entirely interchangeable for all conditions, particularly under those conditions of ambient and superimposed tier mounting where operating temperature is a limitation. Table I shows a comparison of spacing and ambient limitations for 15- and 25-kvar units.

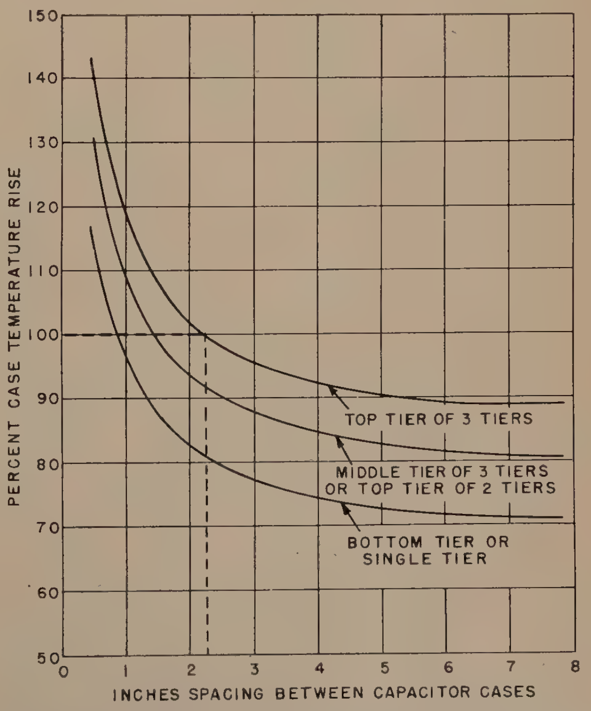


Fig. 13. Typical curves for ventilated indoor low-voltage housed capacitor assembly of 15-kvar units, showing percent case temperature rise versus spacing between unit cases. A single isolated capacitor unit not enclosed would have a 60 percent case temperature rise on the scale shown

TABLE I: MAXIMUM PERMISSIBLE AMBIENT TEMPERATURE RATING

Arrangement	15-kvar Units	25-kvar Units
	(Degrees Centigrade)	
(1) Outdoor in single row, single tier unrestricted ventilation	50	46
(2) Outdoor in two rows, three tiers maximum, unrestricted ventilation	46	40
(3) Indoor in two rows, single tier unrestricted ventilation	40	40
(4) Indoor or enclosed, in two rows, three tiers maximum, unrestricted ventilation	40	40*
(5) Enclosed outdoor or indoor, in multiple rows and tiers with forced ventilation (8 cu ft per min per kvar per deg C rise with 50 C max air-out temperature) and forced circulation about units	46*	40*

*NOTE: Forced circulation of air about unit surfaces is necessary for these ambient ratings.

The ambient ratings given in Table I are based on a minimum horizontal spacing of 2½ in. between capacitor cases of the 25-kvar units and 3½ in. between the cases of 15-kvar units, except that single-tier 15-kvar units also may be spaced 2½ in. minimum between units for a 40 C ambient rating. (The 15-kvar units are 4 in. wide; 25-kvar units are 5 in. wide.)

Forced Ventilation

It is usually expedient and economical to use forced ventilation for higher ambients than those listed in Table I and for limited-volume installations to conserve space. The unit container-surface rise may be reduced several degrees by directing a fan at a group of capacitor units as done in large equipments. A standard 12-in. transformer-type cooling fan will supply air to 12 units in a single row or 24 units in two rows side by side. Thermostatic control of such fans is desirable, since maximum ambient conditions are usually infrequent. Forced ventilation of an enclosure in which capacitors are installed is necessary where the limiting inlet air temperature may be exceeded. If all the capacitor losses must be carried out of the enclosure by air circulation, a volume of eight cubic feet per minute per degree C per kvar nominal rating will give an air temperature rise of one degree C. The allowable air temperature rise will depend on whether forced air circulation about units is provided and on incoming air temperature. The outgoing air temperature generally should not exceed 50 C.

TABLE II: WITHSTAND TEST VOLTAGES

Standard Rated Voltage	Maximum Permissible Operating Voltage	Terminal-to-Terminal Test Voltage Alternating Current	Terminal-to-Terminal Test Voltage Direct Current	Terminal-to-Case Test Voltage Alternating Current
230	253	500	1000	10,000*
460	506	1000	2000	10,000*
575	633	1200	2400	10,000*
2400	2640	5000	15,000	19,000
4160	4575	9000	27,000	19,000
4800	5280	10,000	30,000	26,000
7200	7920	15,000	45,000	26,000
7960	8755	16,600	49,800	26,000
12,470	13,720	25,000	75,000	34,000
13,800	15,180	28,800	86,400	34,000

*NOTE: Indoor units rated only 230 volts may be tested at 3000 volts rms and units rated 460 or 575 volts may be tested at 5000 volts rms.

Since it is difficult to calculate a heat balance for a capacitor unit operating with exposure to normal atmospheric conditions, test measurements are more practical. Temperature records are shown in FIG. 14 for a typical daily cycle of ambient changes, sun radiation effects, and operating temperatures. Bright sun causes about three degrees C higher temperature rise in a single unit as effective average. More effect is obtained in the top tier of an outdoor housing because of sun radiation on the roof and sides.

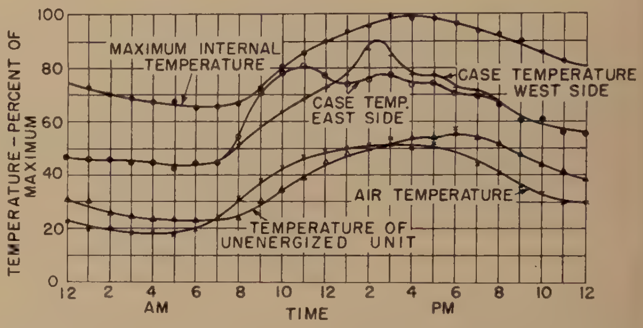


Fig. 14. Typical daily temperature cycle of 25-kvar Pyranol capacitors at rated kva mounted in standard pole-type hangers with 4½ in. spacing between case sides, in July sun

VOLTAGE EFFECTS

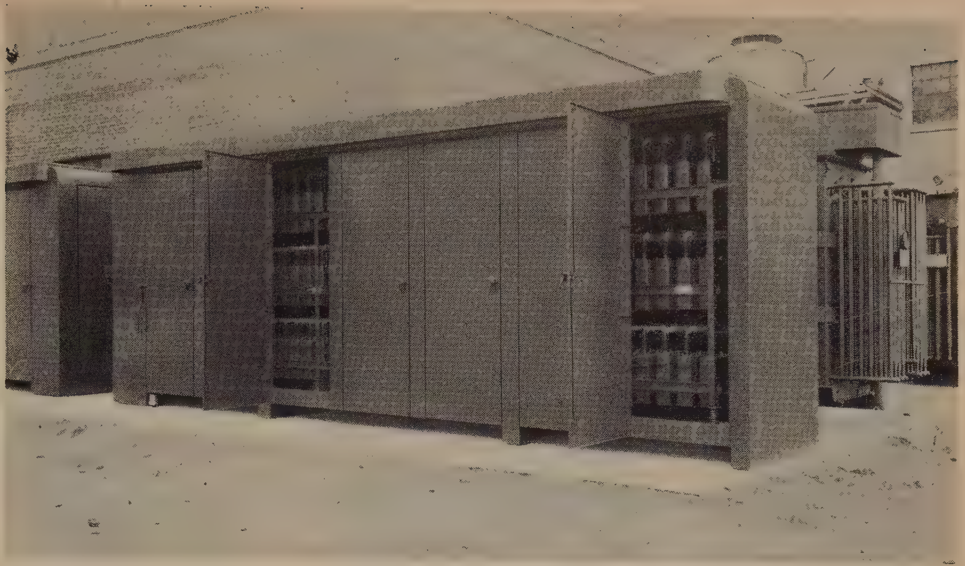
A capacitor unit is most carefully designed to meet stipulated voltage conditions. While actually there is a wide range in voltage effect dependent on frequency, temperature, and time, the discussion of two important general classes seems worthwhile at this point.

Continuous Voltage Effects

Continuous overvoltage causes a relatively large increase in temperature rise because of increased losses which vary almost directly with operating kvar. For example, 5 percent over nominal voltage operation causes 10 percent higher temperature rise. This fact, together with another important one, namely, that capacitors cause a voltage rise at the point in the circuit where connected, makes it desirable to rate capacitors near the maximum continuous voltage to be encountered for a given circuit rating. The average permissible voltage is 105 percent of rated voltage over any 24-hour period. This limitation applies on terminal-to-terminal rating. Terminal-to-case overvoltage rating is not limited by heating because of the very low dielectric losses involved.

Transient Voltage Effect

The transient overvoltage which a capacitor can withstand has been established by many years of service experience. The maximum permissible voltage for regular operating practice, such as for daily cyclic variation, is 110 percent of nominal rating. Switching,



An installation of capacitor equipment, rated 5100 kvar, 13,800 volts Y, three phase, 60 cycles. Through the open doors the assembly of 25-kvar units and individual fuses on an insulated rack is visible

circuit-fault conditions, and lightning surges may cause peak voltages much higher, which are not readily determined and for which no stipulated limit has been set. Capacitors subjected to such transient overvoltages normally encountered in service have been found to have satisfactory life with factors of safety as established by the overvoltage tests specified by NEMA Standards 45–100 and shown in Table II. Capacitors which pass these tests withstand overvoltages equal to, or higher than, other electrical apparatus designed for the same circuit class.

Transient overvoltages on the circuit to which a capacitor is connected should be limited by properly selected and applied lightning arresters.

KVAR, CURRENT, AND FREQUENCY RATINGS

The current supplied to a circuit by a capacitor is dependent on voltage and frequency. The voltage waveshape may include various amounts of distortion from sine-wave form, because of higher harmonic frequency content. Therefore, the current rating must allow for currents at fundamental rated frequency and for some additional amount at harmonic frequencies. Also, with a 0 to +15 percent tolerance of nominal kvar rating, the average is always above nominal. Consequently, the maximum kvar rating must allow for both overvoltage and overcurrent.

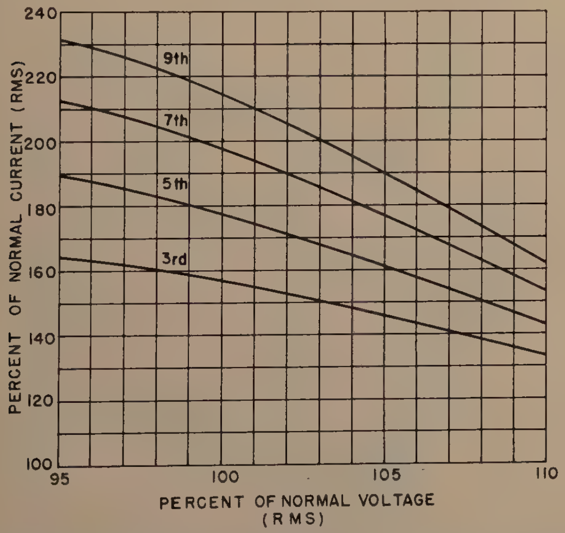


Fig. 15. Allowable percent current overload on capacitors with a single harmonic superimposed on 60-cycle fundamental voltage to give a total of 135 percent kva loading

$\text{kva}_{\text{60-cycle}} + \text{kva}_{\text{harmonic}} = 135$ percent of rated kva

rms volts $= \sqrt{(\text{60-cycle volts})^2 + (\text{harmonic volts})^2}$

rms amperes $= \sqrt{(\text{60-cycle amperes})^2 + (\text{harmonic amperes})^2}$

Based on a number of years of experience, standards have been established such that designers must allow for a maximum permissible kvar of 135 percent of rating as an operating tolerance. The voltage and kvar maximum permissible limits are fixed, leaving current and frequency limits variable over a practical range. Fig. 15 shows permissible maximum currents, assuming harmonic voltages are present. It should thus be apparent that the continuous current-carrying capacity of terminals, leads, buses, and circuit devices used in series with capacitors should usually exceed 135 percent nominal current rating as a minimum.

Peak transient currents may be relatively high during switching or during discharge. A 25-kvar 2400-volt unit charged to 3722 volts, which is the peak of the maximum permissible operating voltage, will discharge through a gap between terminals with a peak current of about 18,000 amp. The discharge is oscillatory at a frequency of approximately 75 kilocycles, lasting only a few cycles. However, because of circuit impedance in typical installations, a bank of units connected in parallel would discharge at a much lower frequency and the total peak current from each capacitor is appreciably less. Current-carrying parts are designed to carry, without damage, the high transient currents encountered in normal service.

SUMMARY

(1). Introduction of a 25-kvar capacitor unit rating ended a 15-year period of standardization on 15-kvar ratings

(2). The 25-kvar unit rating has been well established as the most practical from both standpoints of unit price and ease of application

(Concluded on next page)

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25-KVAR CAPACITOR

(Continued from preceding page)

(3). Consideration of over-all operating characteristics further justifies standardization of a 25-kvar as the logical unit rating

(4). These new 25-kvar units retain all the valued features which have contributed to the success of the 15-kvar units:

(a). Drawn-steel containers, resistance welded at the central flange

(b). Metal-to-glass sealed terminal bushings

(c). Durable finish of tinplate and two coats of baked Glyptal paint

(5). In addition, the 25-kvar units described in this article have:

(a). Mounting interchangeability with 15-kvar units

(b). Improved kraft-paper dielectric which has reduced losses by 25 percent and which gives unusually long service

(c). Reduced weight and size per kvar, consequently lowering costs of bank installations, handling, and over-all space requirements

(d). Reduced capacitor prices 10 to 15 percent per kvar, thus widening the opportunities for applying these units to a power system with more profit to the user.

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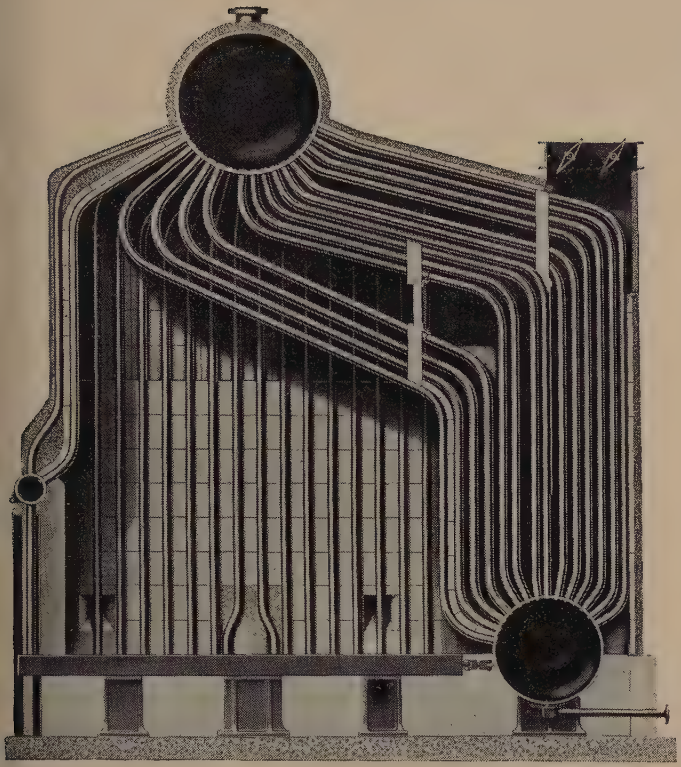

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PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part VI

Effects of atmospheres of combusted fuel gas—purified and unpurified—and catalytically reacted fuel gas in preventing decarburization in various heating processes. Neutralene and Thermalene gas producing equipments described

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COMBUSTED FUEL GAS (UNPURIFIED)

LOW-RATIO combusted gas (unpurified) Item E1a, Table I,* is sometimes used as protective atmospheres for medium- and high-carbon steels in bright-hardening, annealing, and furnace-brazing. This gas is strongly decarburizing, however, because it normally contains about 5 percent carbon dioxide and is saturated with water vapor, both of which are highly decarburizing constituents. Decarburization usually can be eliminated by purifying the combusted gas before it is used as a protective atmosphere, or by employing some other type of nondecarburizing gas to obtain the same advantage. Comparisons will now be made between the decarburizing action of combusted gas (unpurified) and the nondecarburizing action of the same gas when purified, and with other gases.

COMBUSTED FUEL GAS (PURIFIED)—NEUTRALENE

Combusted fuel gas (purified)—now known as Neutralene gas—with its carbon dioxide and water vapor removed, is listed as Item E2, in Table I, in three different conditions: (a) partially burned, (b) nearly completely burned, and (d) completely burned. These various gases have wide applications for heat-treatment of steel without decarburizing.

The partially burned gas E2a is used for: short-cycle annealing, normalizing, hardening, and brazing of medium- and high-carbon steels of the straight-carbon and alloy types; sintering of medium- and high-carbon ferrous metals; carburizing low-carbon steels when used as a carrier gas for natural gas or propane; and for carbon restoration of medium- and high-carbon steels of the straight-carbon or alloy type.

The nearly completely burned and purified gas E2b is used for long-cycle annealing and normalizing of medium- and high-carbon steels of the straight-carbon or alloy types, or high-speed steels.

The completely burned and purified gas E2c is essentially nitrogen. In a typical case, it is enriched with 0.8 percent propane and used for heat-treating high-chromium high-carbon steel dies without decarburization.

PROPERTIES OF NEUTRALENE

Like the atmosphere-gas converters, Neutralene gas producers are available in both low-ratio and high-ratio types. Thus, the partially burned gas E2a is produced by the low-ratio-type machine, and the nearly completely and the completely burned gases, E2b and E2c, are produced by the high-ratio type.

The low-ratio Neutralene gas producer can be operated over a range to give a variety of mixtures of output gas. The most commonly used ratio gives about 10.5 percent carbon monoxide, 15.5 percent hydrogen, 1.5 percent methane, and 72.5 percent nitrogen, with 0.0 percent carbon dioxide and oxygen. The gas generally has a dew point of −40 F or less. Because of its hydrogen and carbon-monoxide contents, this gas is moderately reducing on oxides of various metals, such as iron and copper, at elevated temperatures.

If the fuel gas contains sulfur, this constituent will be removed along with the carbon dioxide in the scrubbing tower of the Neutralene gas producer.

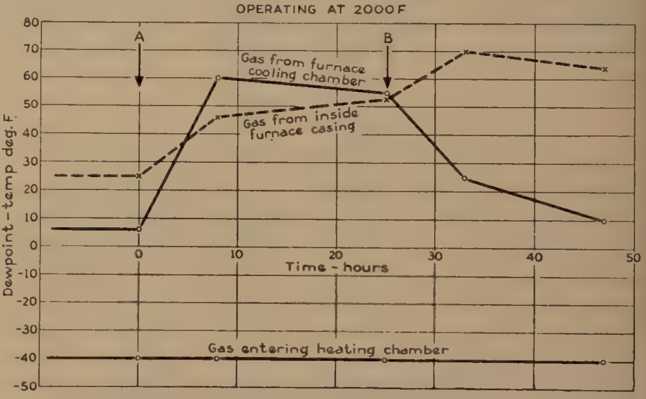

Fig. 42. Dew points of gases entering and leaving box-type electric furnace operating at 2000 F

A: (Entering gas analysis approx. 0.0 percent CO_2, 1.5 percent CH_4, 12 percent CO, 18 percent H_2, 68.5 percent nitrogen.) CO_2 remover cut out of system at this time, allowing CO_2 to increase to about 4 per cent

B: CO_2 remover cut into system again, reducing entering CO_2 to 0.0 percent

Because of its relatively low hydrogen content, the partially burned gas is only mildly inflammable and explosive. It has a specific gravity of about 0.825. In furnaces with normally closed doors, such as the box and roller-hearth conveyor types, the purity of low-ratio Neutralene can be maintained within the furnace

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

*The following will facilitate the location of material published in earlier parts of this serial:

Part	*Issue*	*Figs.*	*Equations*	*Tables*	*Footnotes*
Part I	Nov. 1948, p. 29	1 to 6	None	I to II	None
Part II	Dec. 1948, p. 41	7 to 14	(1) to (18)	III to IV	(1) to (9)
Part III	Feb. 1949, p. 37	15 to 23	None	V to VI	None
Part IV	Mar. 1949, p. 25	24 to 35	None	VII	None
Part V	Apr. 1949, p. 25	36 to 41	None	VIII to X	(10) to (11)

chambers without appreciable difficulty; in mesh-belt conveyor-type furnaces, however, with normally open end doors, maintenance of purity is more difficult. In the latter case, gas-flame curtains burning across the openings, and infiltrating air which is often increased by drafts in the room, are common sources for the presence of H_2O and CO_2 within the furnace. Often the work pieces themselves carry in enough air to be a factor. As a result, to minimize decarburizing, higher rates of flow of gases are normally supplied to furnaces than are needed simply for producing bright work.

The thermal content of low-ratio Neutralene is about 99 Btu and the thermal conductivity with respect to air is only about 1.93. The latter has a favorable effect on thermal losses from the furnace and gives lower heating and cooling rates of the work than obtained with higher-hydrogen gases.

Normal operation of the Neutralene gas producing equipment involves complete removal of carbon dioxide and almost complete removal of water vapor to a dew point of about −40 F. It was previously explained in Equation (13), and related text, that the water-gas reaction requires this purity. If the carbon dioxide is not completely removed from a hydrogen-bearing mixture of low dew point, the water-gas reaction between the CO_2 and H_2 rapidly forms water vapor and CO. This water vapor and the remaining CO_2 then cause a decarburizing action on the steel being treated. Best results can be obtained, therefore, with CO_2-free dry gas.

The water-gas reaction is illustrated in FIG. 42, which shows the dew point of gases entering and leaving a box-type electric furnace operating at 2000 F. The upper solid line illustrates the dew point of the gas leaving the cooling chamber; the broken line that from inside the heating chamber casing. That of gas entering the heating chamber was −40 F throughout the test. Normally, samples taken from a point near the furnace casing showed +25 F with a mixed-gas atmosphere containing 18 percent hydrogen and 0.0 percent CO_2. At point *A*, the CO_2 remover was cut out of the system, which allowed the CO_2 to increase to about 4 percent. The dew points of gas from the heating and cooling chambers gradually changed to about +55 F at point *B*. At this point, the CO_2 remover was cut into the system again, reducing the entering CO_2 to 0.0 percent. Test samples taken from the cooling chamber showed a gradual drop-off in dew point; but that from the furnace casing showed no recovery during the period of the test, perhaps because of contamination from moisture emanating from the brickwork and insulation. These curves show the advantage of completely removing CO_2 from a hydrogen-bearing mixed gas.

Under some conditions, CO_2-free dry gas actually provides a carburizing action, which is often considered desirable. But if it is preferred to have the atmosphere strictly neutral to the steel, by making its carbon potential the same as that of the steel, this can be accomplished by by-passing some wet combusted gas from the Neutralene producer around the drying equipment, to give a controlled, slightly higher dew point. Under this condition, it has been found that the water-gas reaction proceeds slowly in the opposite direction from that just explained, and does not cause the formation of any troublesome CO_2 during short-cycle treatments.

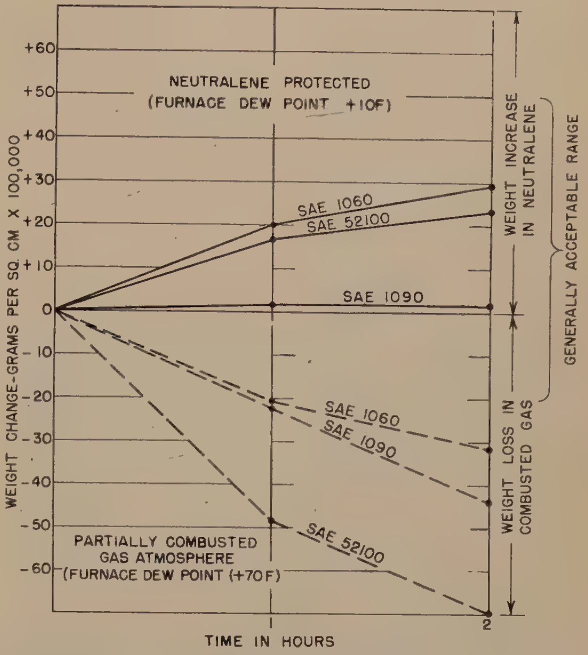

Fig. 43. **The effect of Neutralene and partially combusted gas on SAE 1060, 1090, and 52100 steels as shown by weight-change tests**

FIG. 43 shows, by weight-change tests, the effect of Neutralene on SAE 1060, 1090, and 52100 steels. The samples were held in a box-type electric furnace with open brickwork lining for 1 and 2 hours at 1500 F, then pushed into the water-jacketed cooling chamber and cooled in the same atmosphere as the one in which they were heated. One set of samples was treated in a low-ratio Neutralene atmosphere and another set in a low-ratio combusted-gas atmosphere, to provide a comparison. The samples treated in Neutralene show a slight increase in weight, indicating some carbon pickup, while the samples treated in combusted gas show quite a sharp decrease in weight, indicating decarburization.

The Neutralene treated samples are well within the generally acceptable range of weight change of −20 to +50 gr per sq cm×100,000. However, the carbon pickup shown on SAE 1060 and 52100 steels can be reduced by by-passing some moist combusted gas around the dryer to increase the dew point within the furnace.

Gonser(12) also graphically illustrated the need for CO_2-free dry combusted gas to prevent surface decarburization, in the curves shown in FIG. 44. Steel samples containing carbon varying from 0.10 to 1.0 percent or higher were treated for three hours at 1740 F. The furnace atmosphere was low-ratio combusted-gas containing approximately 9 percent each of hydrogen and carbon monoxide, with varying amounts of carbon dioxide and methane, dried to a low dew point.

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(12) "The Status of Prepared Atmospheres in the Heat Treatment of Steel," by Bruce W. Gonser, *Industrial Heating*, Dec. 1939.

In curve *1* with 5.3 percent CO_2, it is interesting to note that all carbon steels above 0.10 carbon are decarburized by the gas indicated.

Curve *2* shows the results with a gas having only 1.4 percent CO_2. In this instance, carbon steels of 0.4 percent and lower have actually picked up carbon, while those above 0.4 percent have been decarburized, the amount of decarburization increasing with the carbon content. Curve *3*, with 0.9 percent CO_2, shows little change in the medium- and low-carbon range, but some improvement in the higher-carbon steels.

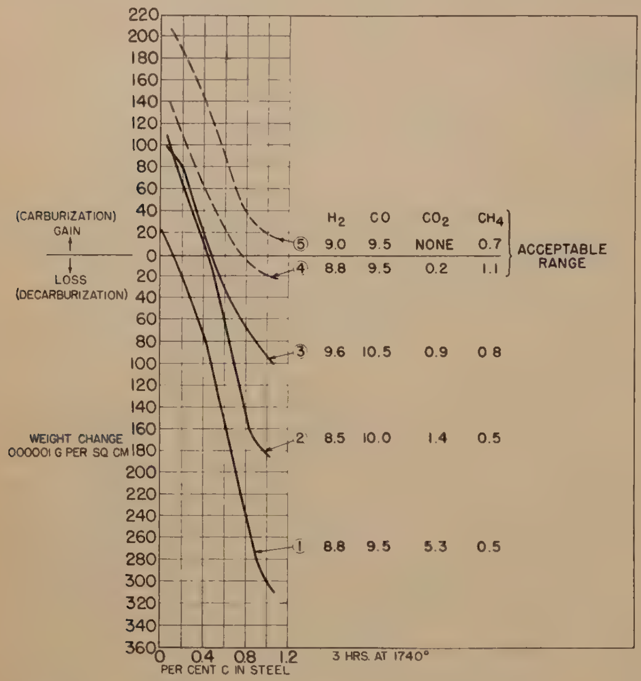

Fig. 44. Gonser's curves showing slight carburizing action of CO_2- free dry combusted gas (curve *5*). Increasing decarburization results with increasing CO_2 content (curves *4* to *1*)

Curve *4*, with 0.2 percent CO_2 and 1.1 percent methane as compared with 0.5 percent methane in curves *1* and *2*, is neutral to 0.7 percent carbon steel and is acceptable from the standpoint of decarburization for 1.1 percent carbon steel. Curve *5* shows the effect of completely removing CO_2, with 0.7 percent methane. In this instance, all the steels are carburized, including the 1.1 percent carbon steel.

Introduction of CO_2 into Gonser's dried gases undoubtedly increased the H_2O content by the water-gas reaction to accelerate the decarburization. With the Neutralene gas producer, however, it is easy to maintain 0.0 percent CO_2 and regulate the moisture content to give carbon-potential control equivalent to that illustrated in Fig. 44.

Comparisons between SAE 1060, 1090, and 52100 samples cut from the weight-change specimens, as treated in low-ratio Neutralene and partially combusted gas under identical conditions, are illustrated in Figs. 45 and 46. No surface decarburization can be detected in the photomicrographs of the samples treated in Neutralene; but the white bands at the surfaces of those treated in combusted-gas show carbon-free ferrite and indicate decarburization.

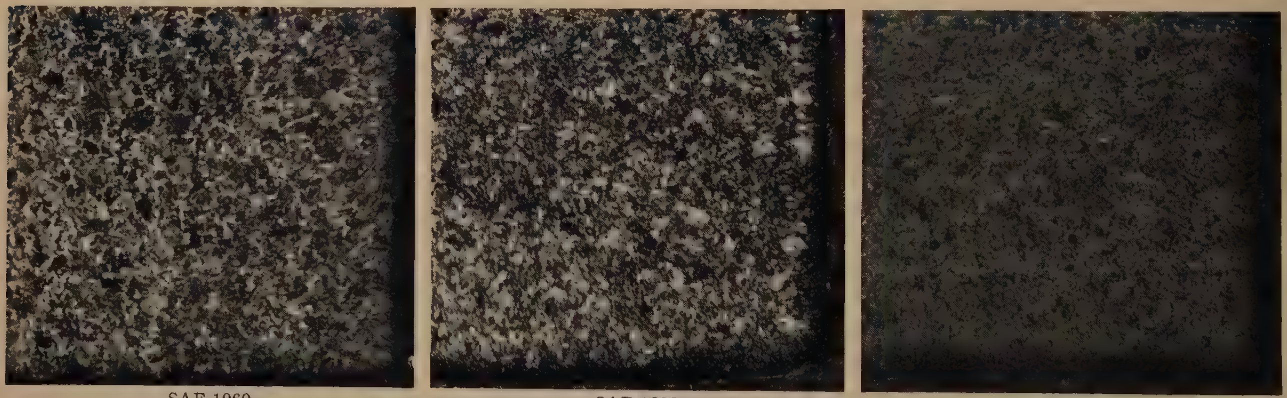
SAE 1060 SAE 1090 SAE 52100

Fig. 45. Photomicrographs (×100) of three different steels treated for two hours in low-ratio Neutralene at 1500 F

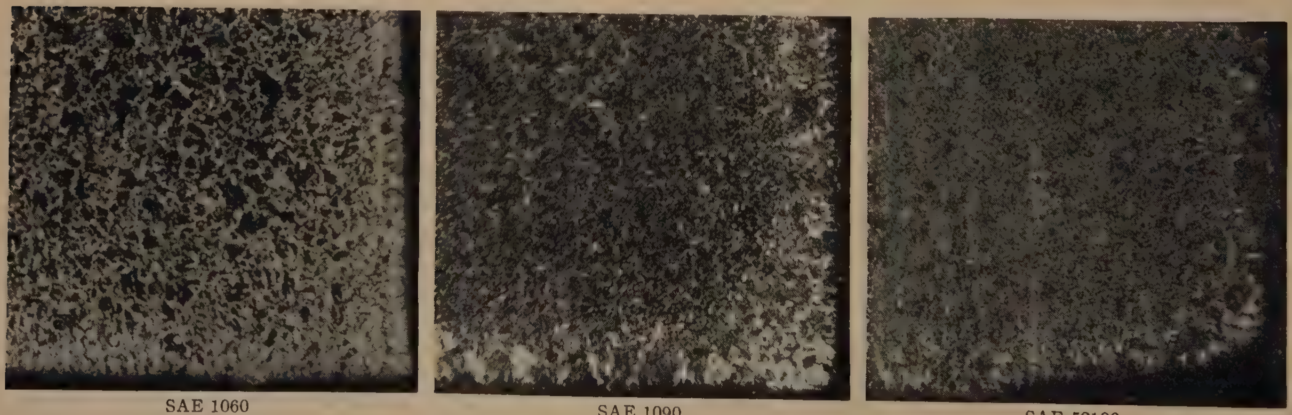
SAE 1060 SAE 1090 SAE 52100

Fig. 46. Photomicrographs (×100) of three different steels treated for two hours in partially combusted gas under identical conditions as those shown in Fig. 45

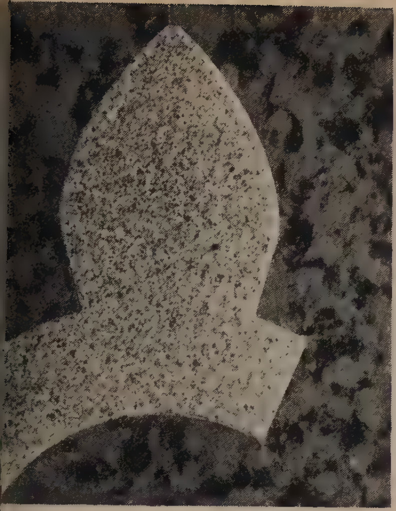

Fig. 47. Photomicrograph (×4) showing cross-section of a tooth of an iron oil-pump gear, made by powder metallurgy, which has been sintered in a Neutralene atmosphere at 2050 F.

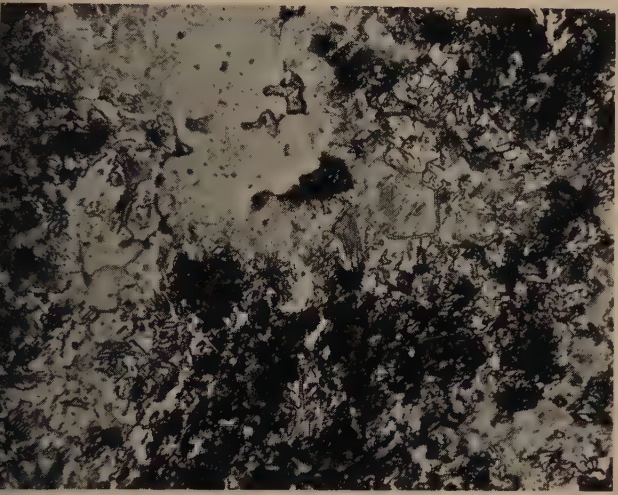

Fig. 48. Photomicrograph (×500) showing the approximately eutectoid structure at the center of the tooth illustrated in Fig. 47

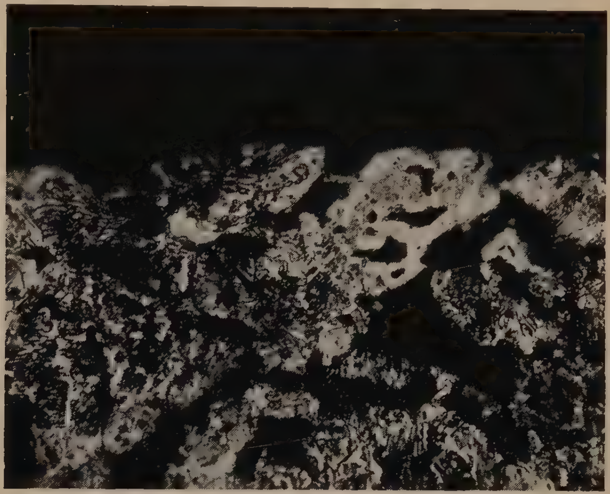

Fig. 49. Photomicrograph (×500) of the structure at the edge of the tooth shown in Fig. 47

FIG. 47 is an enlarged cross-section of the tooth of an iron gear, made by powder metallurgy, which has been sintered at 2050 F in Neutralene atmosphere. The approximately eutectoid composition at the center of the tooth is shown by photomicrograph in FIG. 48. The microstructure at the surface of the tooth is shown in FIG. 49. From the latter two photomicrographs, it is evident that the microstructure at the surface is comparable with that at the center, and it seems reasonable to conclude that there is no noticeable loss of carbon from the iron.

No doubt conditions are more favorable in sintering iron parts containing free graphite at 2050 F than in copper-brazing assemblies made of high-carbon steel. For example, there apparently is a surplus of free graphite in the iron compacts to allow rapid diffusion of carbon into the ferrite and help maintain equilibrium conditions; also, there is a carbonaceous vapor emanating from and surrounding the compacts during heating which undoubtedly gives some surface protection. Nevertheless, the atmosphere must be very good to permit obtaining results such as those just described.

Serious decarburization can be detected by a standard hardness tester. Slight decarburization may not be indicated by such a tester but may be revealed by comparison of readings between those taken on a Rockwell standard machine and on a Rockwell "superficial" machine.

A comparison test on Neutralene protected samples of representative medium- and high-carbon steels, such as SAE-1060, 1090, and 52100, resulted in the record shown in Table XI. After small pieces were cut from the weight-change samples for making the photomicrographs shown in FIGS. 45 and 46, hardness tests were conducted on the remaining parts. These specimens were placed in the box-type furnace for 20 min at 1500 F, either in Neutralene or combusted-gas atmosphere, depending on the atmosphere to which they had been exposed during the weight-change tests. Then they were transferred through air to an oil quench.

Table XI shows that, in all the tests on the Neutralene protected samples, the R15N readings converted to RC were greater than the direct RC readings, indicating that no surface decarburization had occurred. However, tests on the samples treated in combusted gas gave readings on the R15N scale, which, when converted to RC, were less than the direct RC readings, indicating that surface decarburization had occurred.

TABLE XI

COMPARATIVE HARDNESS READINGS OF SAMPLES TREATED IN NEUTRALENE AND COMBUSTED GAS ATMOSPHERES

	1 Hr in Heat(1)				2 Hr in Heat(1)			
Steel Code, SAE	Neutralene Atmosphere		Combusted Gas Atmosphere		Neutralene Atmosphere		Combusted Gas Atmosphere	
	A	B	A	B	A	B	A	B
1060.....	62	63	53	47	63	65	51	41
1090.....	66	67	63	60	66	67	62	58
52100.....	65	66	61	60	66	67	60	58

A. Direct Rockwell "C" hardness.
B. Rockwell 15 N "superficial" hardness converted to "C" Scale.
(1) Period of time samples were in furnace for weight-change test. Reheated for 20 min. at 1500 F, then oil quenched to obtain hardness data.

These comparative tests on samples treated in Neutralene and combusted-gas atmospheres show the effectiveness of Neutralene for heat-treating medium- and high-carbon steels without decarburization.

PROPERTIES OF NEARLY COMPLETELY BURNED FUEL GAS (PURIFIED)

The nearly completely burned fuel gas (purified) Item E2b, Table I, contains about 2 percent each of carbon monoxide and hydrogen, 96 percent nitrogen, dewpoint −40 F. It has 0.0 percent of carbon dioxide, oxygen, and methane. Because of its low hydrogen and carbon-monoxide content, which are allowed to be present to counteract any leakage of air, there is no tendency for etching during long-cycle annealing and normalizing treatments, such as with batches of coiled-steel strip. The gas described is not inflammable or explosive when mixed with air. Its specific gravity is about 0.954, approximating the weight of air; its thermal conductivity is about 1.12 with respect to air.

COMPLETELY BURNED FUEL GAS (PURIFIED)

Completely burned fuel gas (purified) Item E2c, contains about 0.7 percent each of carbon monoxide and hydrogen, 98.6 percent nitrogen, dew point −40 F. It has 0.0 percent each of carbon dioxide, oxygen, and methane. Moreover, it is practically inert and, as such, is used as nitrogen atmospheres for some applications. When decarburization is a factor, it is sometimes enriched with a small amount of propane to counteract leakage of air and water vapor into the system. Also, it is not inflammable or explosive when mixed with air. Its specific gravity is about 0.97 or approximately the same weight as air; its thermal conductivity is 1.04 relative to air.

COST OF NEUTRALENE

The cost of operating a Neutralene gas producer is very low, as indicated in the righthand column in Table I, and in Table XII. The various components going into the cost estimates, their quantities, and their assumed rates are listed in Table XII to show how the operating costs are determined. Data are given for both coke-oven and natural-gas consumption. If propane is used, its consumption will be about half that of natural gas; and, if butane is used, about one-third.

MANUFACTURE AND DISTRIBUTION

A typical Neutralene gas producing equipment is shown in Fig. 50 and its flow diagram in Fig. 51. As indicated at the left of the flow diagram, fuel gas and air are drawn through visual flowmeters into a gas-combustion controller consisting of a proportioning mixer which regulates and controls the input air-gas ratio, and a motor-driven compressor. The air-gas-mixture line leaving the compressor leads to a volume-control valve, an automatic fire-check, and a burner with refractory screen. The burner fits into the top of the vertical combustion chamber mounted in the boiler of the reactivating tower. The combustion chamber is filled with a bed of special catalyst brick like that shown in Fig. 27, which assists the reactions in proceeding to completion.

On leaving the combustion chamber, the product gases pass through a straight-tube surface cooler which partially condenses out the water vapor. The cooled gas and condensate then enter a velocity-type water separator, and the condensate drips from a trap into a drain. The gas then passes through a CO_2 absorbing tower, in which the CO_2 is removed to 0.0 percent. The absorbing liquid is a water solution of monoethanolamine which flows down from the top over a large area of filler material. From this tower, the gas passes through a cooler, and the condensate returns to the bottom of the absorbing tower into the system. The gas then leaves the Neutralene producer and goes through a refrigerated gas cooler, which reduces the dew point to about +40 F, thence to a regenerative-type dryer, which further reduces the dew point to about −40 F. From the dryer, the gas goes directly to the furnace or other point of use.

The absorbent, after making contact with the gas, collects at the bottom of the absorbing tower and is continuously drawn off by means of a motor-driven pump. It is forced through a heat exchanger, where it is warmed before entering the top of the reactivating tower. Here it travels down over surface material, similar to that used in the absorbing tower, becomes further heated by rising gases and vapors, and the CO_2 and sulfur compounds are driven off. As the absorbent accumulates in the bottom of the boiler, additional

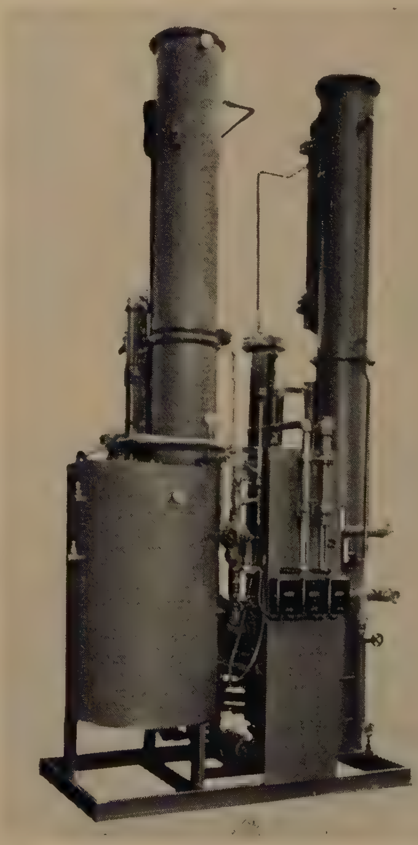

Fig. 50. A typical Neutralene gas producing equipment

TABLE XII: NONDECARBURIZING PROTECTIVE ATMOSPHERES

Materials consumed, and operating cost per M Cu Ft

Item	Protective Atmosphere	Fuel Gas Consumption Cu Ft per Hr		Electric Power Kw-hr per Hr	Cooling Water Gal per Hr	Atmosphere Cost* per M Cu Ft	
		Coke-oven Gas	Natural Gas			Coke-oven Gas Fuel	Natural Gas Fuel
E.	Combusted fuel gas						
	(2). Purified						
	(a). Partially burned						
	(I). CO_2-free and dry (Neutralene)	370	155	4	477	$0.32	$0.14
	(b). Nearly completely burned						
	(I). CO_2-free and dry (Neutralene)	280	125	4	627	0.27	0.133
	(c). Completely burned						
	(I). CO_2-free and dry (Neutralene)	260	115	4	627	0.25	0.128
F.	Reacted fuel gas						
	(1). With air over catalyst						
	(a). Completely reacted (Thermalene)						
	(I). Gas-heated	700	350	2	150	0.52	0.21
	(II). Electrically heated	410	200	12	100	0.42	0.23

* Costs include only materials consumed such as power, gas, and water. They do not include factors for obsolescence, installation, maintenance, labor, etc. The estimates have been based on the following unit costs:

Power—$0.01 per kw-hr
Natural gas—$0.50 per M cu ft
Coke-oven gas—$0.70 per M cu ft
Water—$0.05 per M gal

amounts of the impurities are removed. The CO_2 and H_2S rise to the top of the tower and are discharged after passing through a reflux condenser and a separator which remove any residual absorbent.

The hot reactivated CO_2 absorbent at the base of the reactivating tower is continuously drawn off and forced through the heat exchanger by means of a second motor-driven pump. Then it is passed through a surface cooler and flowmeter, to an inlet near the top of the absorbing tower, where the circuit is completed.

Heating of the absorbent in the reactivating tower is accomplished by thermal losses from the combustion chamber, which would otherwise be wasted heat. This feature saves about 18 cents per M cu ft in operating cost because without it the boiler would consume about 18 kw-hr per hr in electric energy which, at 1 cent per kw-hr, would cost 18 cents.

BASIC UNITS FOR NEUTRALENE

Prior to the development of the combination Neutralene gas producer which incorporates the combustion system and CO_2-removal system in a single unit, separate basic units were employed which produced essentially the same gas. These units consisted of a separate atmosphere-gas converter, a CO_2-removal equipment consisting of the absorbing and regenerative towers with their necessary accessories, and the moisture-removal equipment. Many of these installa-

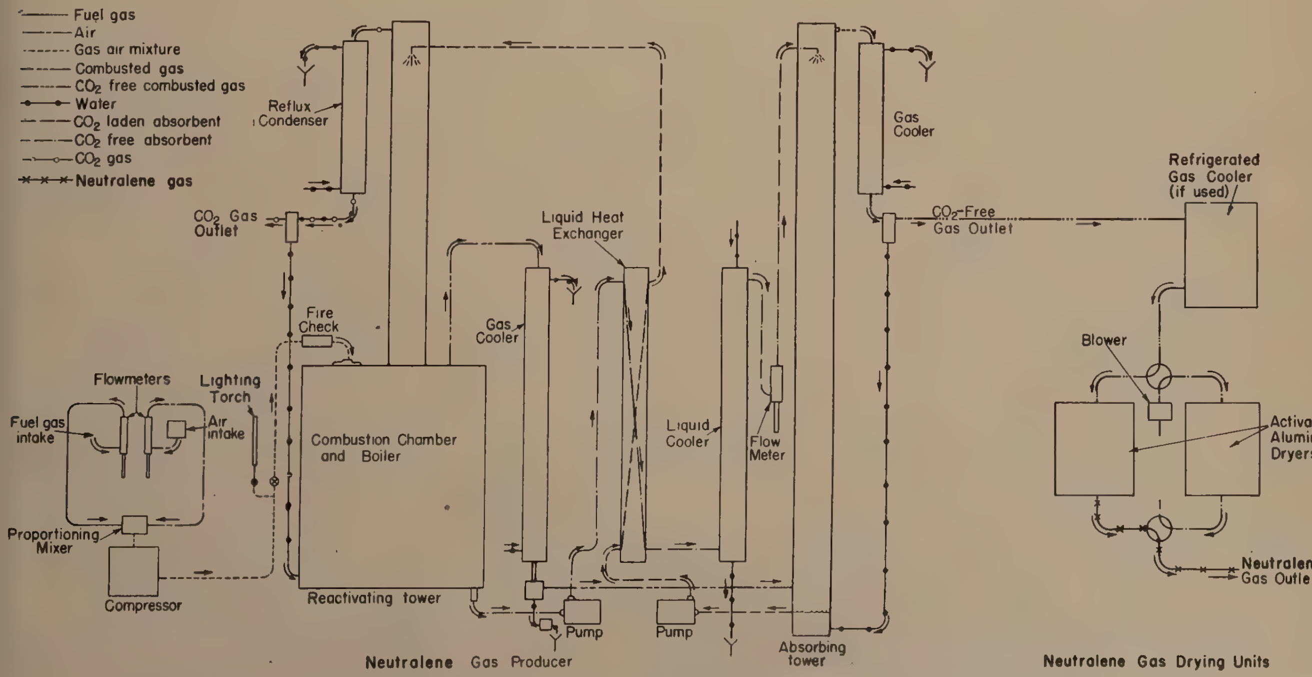

Fig. 51. Flow diagram of the equipment shown in Fig. 50, plus gas-drying units

tions were made and are still in operation. The present Neutralene gas producer, however, offers economic advantages, such as 10 to 20 percent lower initial investment, 55 percent less floor space occupied, and a saving of about 18 cents per M cu ft output in operating cost.

Catalytically Reacted Fuel Gas—Thermalene

Reacted fuel gas with air over catalyst, Item F1a in Table I—now known as Thermalene gas—is employed for all of the applications listed for combusted fuel gas (purified) partially burned—Neutralene—Item E2a.

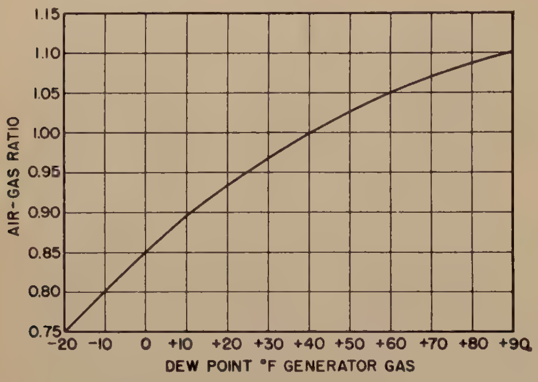

Fig. 52. Average air-gas ratios to produce a desired dew point of atmosphere as obtained from a Thermalene gas producer when coke-oven fuel gas is used

PROPERTIES

The Thermalene gas producer has a range of operation which is effected by adjustment of the air-gas ratio similar to the atmosphere converter. At a low ratio of about 2.5 volumes of air to 1 of natural gas, the output gas contains about 19 percent carbon monoxide, 38 percent hydrogen, 1.5 percent methane, and 41.5 percent nitrogen. It contains 0.0 percent each of carbon dioxide and oxygen, and the dew point is about −10 F.

As the ratio is increased, however, the water-vapor content increases, and at about 45 F dew point, there is some CO_2. The ratio can be increased until the CO_2 becomes as high as about 1 percent.

Because of its rather high carbon-monoxide and hydrogen content, the gas is quite inflammable and explosive and must be handled with respect, the same as dissociated ammonia and hydrogen. It is somewhat lighter than air, having a specific gravity of 0.622. It has a high thermal conductivity with respect to air, being about 3.23. This means that the thermal losses from a furnace in which this gas is used as a protective atmosphere will be higher than with lower-conductivity gases, as illustrated in Part III, Fig. 15, and related text. The thermal content is about 200 Btu.

In Part II of this serial, in the section on decarburizing reactions, the effect of water vapor was described briefly. When annealing carbon steels, the carburizing action or "carbon potential" of the atmosphere can be adjusted by controlling the water-vapor content to produce an atmosphere which would be neutral to the particular steel being treated. The control of the dew point is produced by simply adjusting the air-gas ratio. However, very close control of the ratio is necessary when operating below a +10 F dew point, since incomplete carbon conversion may cause a slow buildup of carbon in the reaction chamber.

Fig. 52 shows average values of the air-gas ratios to produce a generator gas of a specified dew point when using coke-oven fuel gas. This curve illustrates the variation in dew point resulting from a comparatively small change in ratio. It also indicates the importance of a very consistent fuel gas for use with this type of generating equipment. Fuel gases which are produced by mixing several types of gases may vary too much for constant results. For example, changes in the amounts of hydrocarbon gases, such as propane and butane, may change the specific gravity sufficiently to give erroneous readings on indicating flowmeters and cause periodic or constant operation at improper ratios. This then results in fluctuating or continuously high (or low) dew point of the output gas even though the indicated air-gas input ratio is correct.

To illustrate the effect of Thermalene atmosphere on four different carbon steels, results of some weight-change tests are listed in Fig. 53. The furnace used was of the open-brickwork type with exposed electric heating units. The dew point of the atmosphere samples taken from inside the furnace chamber was 0 F; the dew point of the entering gas was about −15 F; the temperature of the furnace was 1500 F. Two sets of samples were treated: one for one hour and the other for two hours. These curves show a considerable increase in carbon for all samples but they still fall within the generally acceptable range for maximum surface hardening. For shorter heating cycles, such as are encountered in a continuous-type hardening furnace, the amount of carbon pickup would be correspondingly lower and of little significance. To reduce the amount of carbon pickup and obtain a neutral atmosphere, the air-gas ratio can be increased to raise the dew point, which in turn decreases the carbon potential. For instance, a 0.60 carbon steel requires a furnace dew point of about +35 F at 1500 F.

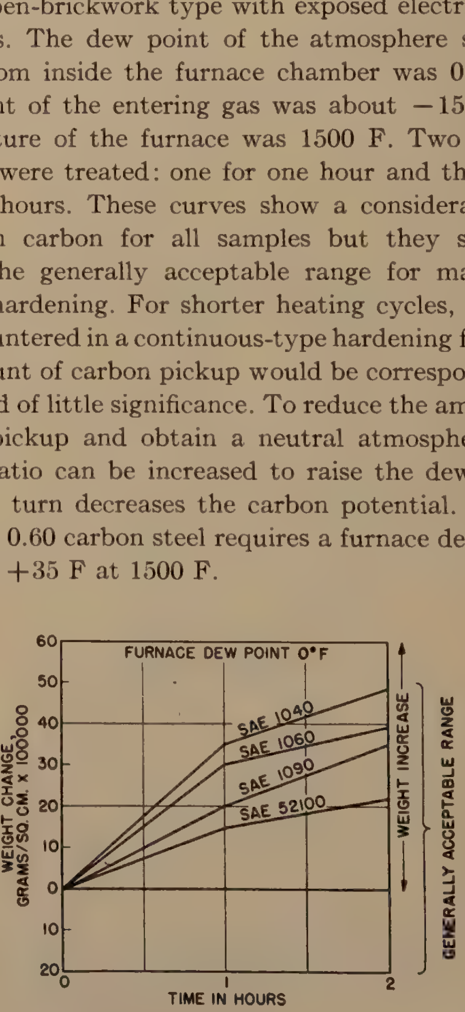

Fig. 53. Results of weight-change tests, using an atmosphere of catalytically reacted fuel gas (Thermalene) similar to F1a listed in Table I

OSTS

The cost for materials when operating a Thermalene as producer under the conditions previously stated is bout 21 cents per M cu ft output. This is based on the aterial consumption and rates specified in Table XII.

IANUFACTURE AND DISTRIBUTION

A flow diagram of a typical Thermalene gas producer s shown in Fig. 54. As indicated at the left, fuel gas nd air are drawn through visual flowmeters into a gas-ombustion controller consisting of a motor-driven ompressor and a proportioning mixer which regulates nd controls the input air-gas ratio. The air-gas-mixture ine leaving the compressor leads to a volume-control valve, an automatic fire-check, and into a catalyst-filled reaction retort. The retort is mounted in a gas-heated chamber which provides heat for the endothermic reaction within the retort. The reacted gas passes out of the retort through a surface cooler and water separator with trap, and the processed gas goes on to he furnace or other point of use. When operating at he critical ratio to produce low-dew-point gas, the surface cooler has no function, but it is provided for use n starting up the equipment and when operating on higher ratios which produce high-dew-point gases.

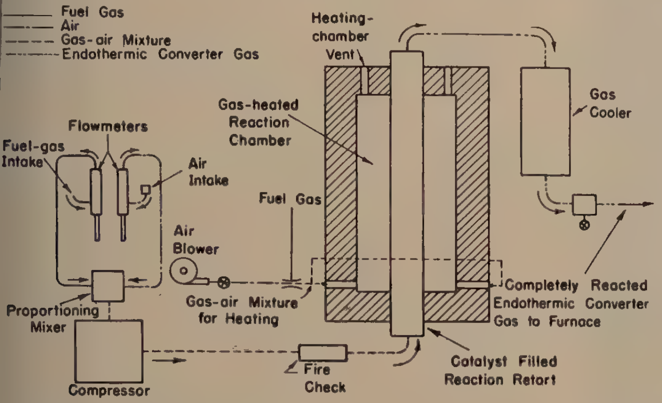
Fuel Gas
Air
Gas-air Mixture
Endothermic Converter Gas
Heating-chamber Vent
Gas Cooler
Gas-heated Reaction Chamber
Flowmeters
Fuel-gas Intake
Air Intake
Fuel Gas
Air Blower
Completely Reacted Endothermic Converter Gas to Furnace
Proportioning Mixer
Gas-air Mixture for Heating
Fire Check
Catalyst Filled Reaction Retort
Compressor

Fig. 54. Schematic diagram of Thermalene gas producer for furnace atmospheres

Burners in the bottom of the reaction chamber are supplied from a blower with zero-governor mixer, which feeds the air-gas mixture for combustion around he retort. The products of combustion are vented from he top of the chamber into an external exhaust hood. Temperature is controlled by means of an automatic hrottling valve in the input air line, actuated by a emperature-control instrument having thermocouples n the reaction chamber.

When alloy retorts are employed, the reaction-hamber temperature is about 1900 to 2000 F. In this emperature range, electric heat can be employed. With efractory retorts, an operating temperature of about 2200 F is used; this insures more complete reactions with less possibility of carbon deposit and plugging. Equipments of this type are generally limited to smaller izes—from 250 to 2500 cfh—with multiple units being used for greater capacities.

(To be continued)

Tube-type resistor with metal casing removed, showing wire and Glasohm windings.

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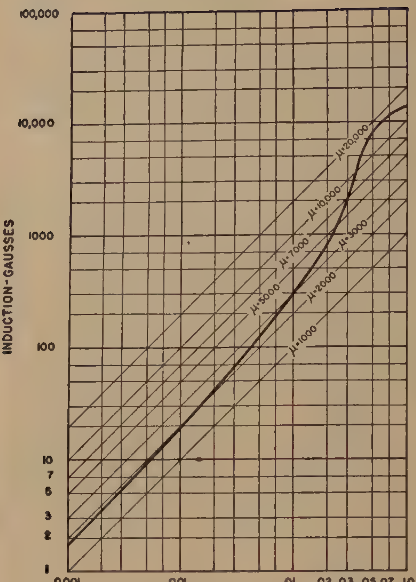
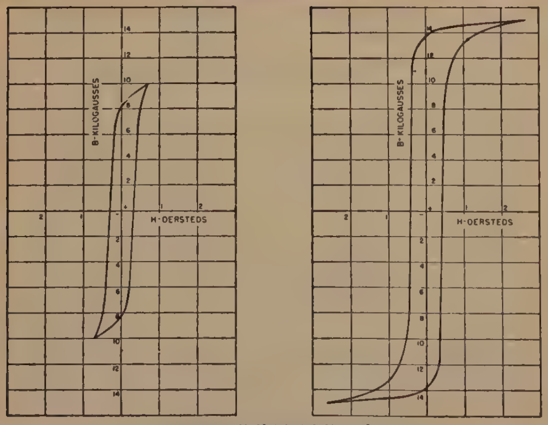
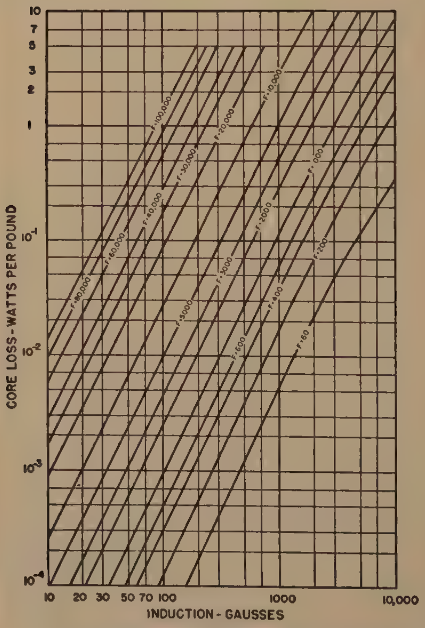


D-C. MAGNETIZATION CURVE FOR A SAMPLE OF 0.002″ ARMCO THIN-GAGE ELECTRICAL STEEL



HYSTERESIS CURVES OF A SAMPLE OF 0.002″ ARMCO THIN-GAGE ELECTRICAL STEEL



CORE LOSS CURVES FOR A SAMPLE OF 0.002″ ARMCO THIN-GAGE ELECTRICAL STEEL

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SURGE PROTECTION IN A MODERN WATTHOUR METER

Today's metering requirements lend importance to the problems of surge protection which are solved in the design of a new watthour meter

G. Dean Williams

By F. H. BUSCH and G. D. WILLIAMS
Meter Engineering Division, West Lynn Works
General Electric Company

RECENT trends in metering practice have imposed additional requirements upon the design of watthour meters, particularly from the viewpoint of surge protection. Most significant has been the change in the installation location with the meter ahead of the fuse and switch box, remote from it, and usually out-of-doors. This change, combined with the increasing number of meters installed on rural distribution systems, has clearly indicated that surge protection is of primary concern in evaluating the merits of any particular meter design.

Consideration of the over-all problem of surge protection for watthour meters is particularly appropriate at this time. Never before has the cost of labor in testing and maintaining the meters on a utility system been so great. In addition, maintenance of the growing number of meters installed on rural distribution systems, where lightning hazards are the most severe, is complicated by the greater distances involved.

Reduction of maintenance was the primary objective for the development of a new watthour meter (Figs. 1 and 2). To accomplish this end, detailed consideration was given to the surge protection problem and to the provision of adequate protective features. By reducing the hazards of damage from surges, longer service periods without attention are possible. This objective has been further insured by other improvements. For example, the problem of bearing wear inherent in previous meter designs has been solved by suspending the rotor by means of two small magnets, one fixed to the meter frame and the other to the top of the shaft of the rotating disk. In this manner the previous use of a pivot or ball on sapphire bearing, operating at high bearing pressures, has been eliminated.⁽¹⁾

TYPES OF SURGE PROTECTION REQUIRED

The modern meter, as exemplified by the design described in this article, must be protected from surge-current demagnetization of the permanent magnets and also from insulation damage caused by voltage flashovers. The types of protection and the meter components involved are as follows:

(A). Protection from demagnetization
  (1). Braking magnets
  (2). Suspension magnets

(B). Protection from insulation damage
  (1). Current coil
  (2). Potential coil
  (3). Terminals and mounting

(C). Protection from mechanical damage
  (1). Disk and shaft

That surge currents can be great enough to demagnetize the braking magnets is recognized. Damage of this type is of considerable concern to the operating company as it results in over-registration of the meter and, consequently, serious customer-relation problems. During the past fifteen years this hazard has been effectively reduced by using alnico permanent magnets, or by encasing the magnets in a conducting covering.

The suspension of the meter disk and shaft by new magnetic components has been made possible by

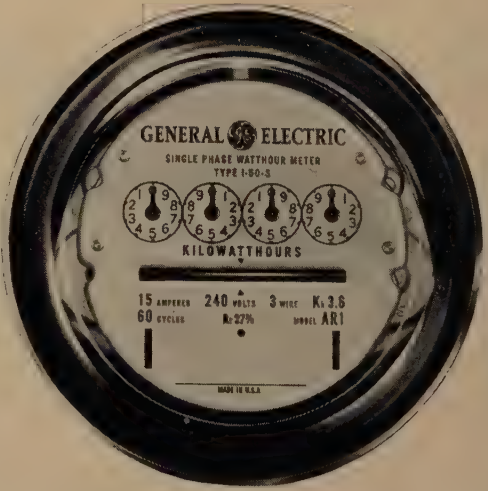


Fig. 1. New detachable type of single-phase watthour meter

Presented as a paper at the AIEE Winter General Meeting in New York City, Jan. 31 to Feb. 4, 1949.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

(1)"A New Watt-hour Meter," by I. F. Kinnard, *Electrical Engineering* vol. 67, No. 7, July 1948, p. 627.
"Revolutionary Advances in Watthour Meter Design," by I. F. Kinnard, General Electric Review, vol. 51, June 1948, p. 11.

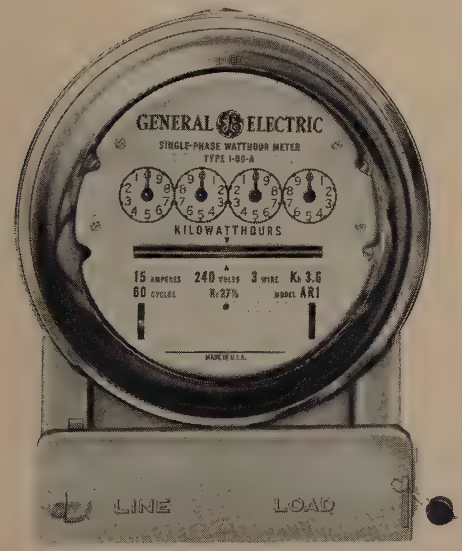
ecent developments in magnetic materials. Protection f these magnets, as well as the braking magnets, must e provided.

Damage to insulation from lightning surges is the ame for a watthour meter as for other electrical equipnent. The potential coil is made of many turns of small vire and is insulated from the frame or mounting of the neter. The most likely result of insulation puncture or lashover from the coil to the frame is the burnout of he small wire by either the surge current or the linerequency ground current. This usually leaves the coil pen-circuited, and meter failure is evidenced by loss of egistration. Meter current coils, on the other hand, re relatively heavy conductors and insulation puncture s not likely to result in open circuits. The hazard of hort-circuiting of a portion of its turns is greater, owever, and may result in under-registration of the neter. Terminal blocks or bases are subject to insulaion flashover unless adequate insulation co-ordination s provided. The design considerations involved in proiding this co-ordination are presented later.

The mechanical forces generated by severe surges can listort the watthour meter disk. A strong field in the urrent coils created by short-circuit or surge current, cting on the aluminum disk, repels it violently, and nay distort it sufficiently to prevent free rotation.

raking Magnets

The braking magnets in the meter shown in FIG. 3 tilize alnico 5, a high-coercive magnetic alloy having roperties that make it especially suited to this applicaion. Two C-shaped magnets are mounted diametrically pposite each other on a line passing through the axis f disk rotation. Actually they are cast as inserts in the lie-cast aluminum alloy frame and are completely urrounded by the aluminum. Resistance to demagnetiation by surge currents is attained by taking full advantage of the high coercive force of alnico 5 and by the eddy-current shielding of the aluminum.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LINE
LOAD

Fig. 2. New front-connected type of single-phase watthour meter

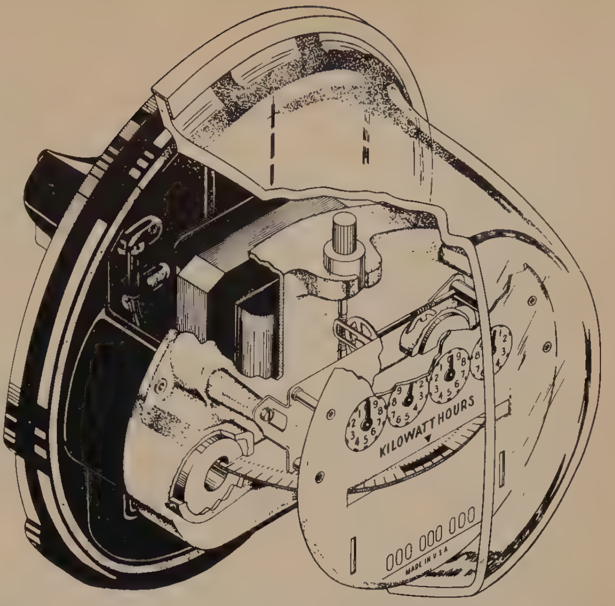

Fig. 3. Diagram of new single-phase watthour meter showing location of braking magnets

Alnico 5 has a coercive force of over 500 oersteds as compared with just over 200 for cobalt steel, and less than 100 for chromium or tungsten steel. This high coercive force has permitted an improved method of providing the stabilizing knockdown given the magnets before use in meters. Previously, the method was to knock down the magnets a fixed percentage of their saturated strength. The improved procedure is to use a demagnetizing field of a uniform strength to give the magnets the stabilization desired. The strength of this demagnetizing field exceeds the field which would be produced in the meter by the highest short-circuit current to which the meter is expected to be subjected. This method gives positive assurance of the stability of the magnets against short-circuit currents. The new method eliminates a hazard inherent in the former method of percent knockdown by which a magnet of high residual but low coercive force appeared satisfactory, even though the magnet lacked sufficient coercivity, the property which gives it resistance to demagnetizing fields. FIG. 4 shows the means of attaining this stabilization in terms of the demagnetization curve for alnico 5. In particular it is to be noted how a magnet having satisfactory saturated strength but poor coercivity is readily detected and rejected when all magnets are subjected to a fixed value of stabilizing field. On the basis of saturated strength both magnets would appear to be equally satisfactory. The field to which all magnets for this meter are subjected is strong enough to demagnetize completely previous types of chrome-steel magnets.

The second way in which resistance to demagnetization by lightning surge currents is attained is the eddy-current shielding provided by the sheath of high-conductivity aluminum enclosing the magnets. Eddy currents induced in the shield are effective in substantially reducing the magnetic field produced by steep-front surge currents as has been previously described.(2)

How effective this modern design is in protecting against decalibration by lightning-type surges is shown in Fig. 5, which gives the results of laboratory tests with surge current values up to 40,000 crest amperes through the neutral conductor of an installation of the detachable type of meter. These results show its definite superiority (Meter *A*) as compared with chrome steel or alnico 2 magnets used in previous designs (Meters *B* and *C*), for the condition of the conductors passing behind the meter vertically (*V*) or horizontally (*H*). A test wave of relatively slow time-to-crest was used to insure obtaining test data as pessimistic as possible.

Suspension Magnets

Surge protection of the suspension magnets, which support the disk with negligible bearing load, is assured by the same features that applied to the braking magnets. The magnetic alloy used for both inner and outer magnets is cunico, which has a coercivity of 700 oersteds. Full advantage of this property is taken by subjecting all magnets to a strong stabilizing field which is greater than the field established by the maximum short circuit or lightning surge current expected. The same principles that are shown in Fig. 4 apply.

In addition, eddy-current shielding is obtained by enclosing the outer magnet in a jacket of conductive die-cast material, as well as by mounting it in an aluminum support. The location of the magnetic suspension (Fig. 6) at the top of the disk shaft is particularly desirable because of its distance from the current coils, which are the source of surge or short-circuit fields. The concentric design of the magnets also contributes to the surge resistance, since the inner magnet is effectively shielded by the outer magnet.

A number of meters with magnetic suspensions have been submitted to both 60-cycle short-circuit tests and to lightning-type surges. Special care was taken to observe any change in the vertical position of the disk that would indicate weakened magnets. Tests were made with 60-cycle short-circuit currents up to 15,000 amperes through the current coils of a 15-ampere meter and with lightning-surge currents up to 40,000 crest amperes through the vertical neutral of a detachable-type-meter installation. Even with the use of a microscope, any change of disk position was difficult to detect and in no case was greater than 0.002 in.

These tests also showed that no damage occurred as a result of mechanical forces created in the disk by the surge-current fields. Strength sufficient to prevent damage has been provided in this meter by a stiff aluminum disk, embossed to further increase its strength. This disk design has been used in previous meter designs and proved satisfactory.

INSULATION CO-ORDINATION

The degree of improvement obtainable by practica improvements in sparkover levels of insulation canno be expected to decrease substantially the hazard o surge damage to the meter insulations. Lightning dis charges are considered to be the discharge of a electric charge between clouds and the earth. This dis charge produces a current flow which will induce voltage across any impedance encountered. The magnitude of the surge current and the steepness of its wave front are often such that the voltage induced across the meter windings would be many times the

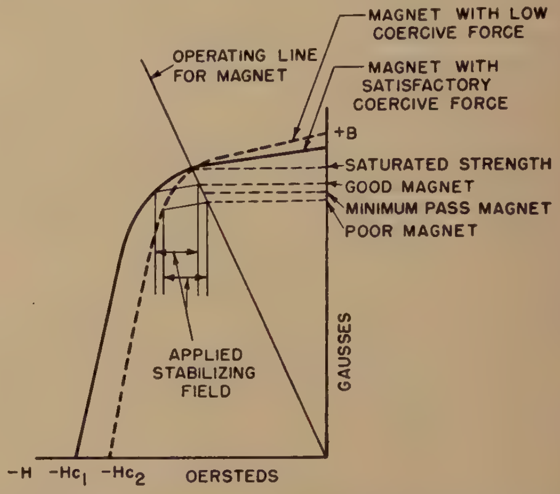

Fig. 4. **B-H curves showing the stabilization of high-coercive magnetic alloy by the application of uniform demagnetizing field**

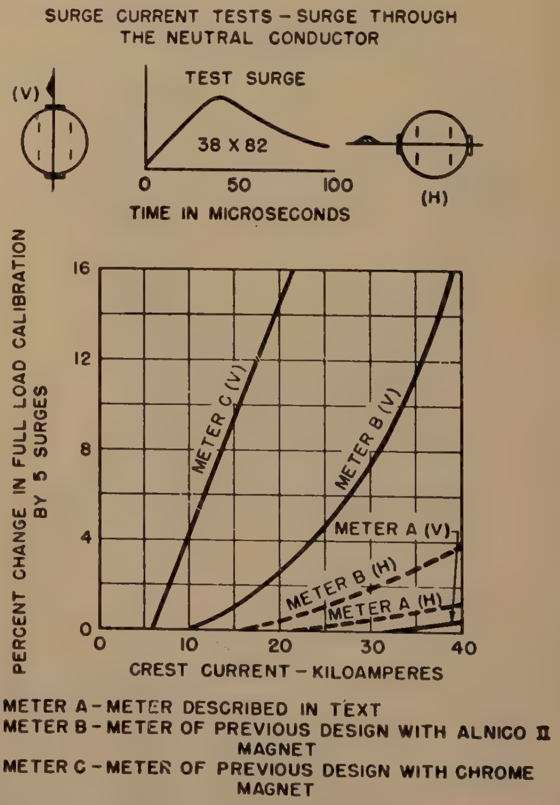

Fig. 5. **Curves showing results of lightning-type current surge tests on calibration of a detachable-type watthour meter**

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(2) "Braking Magnets for Watt-hour Meters," by I. F. Kinnard and J. H. Goss, *A.I.E.E. Transactions*, vol. 60, 1941, p. 653.

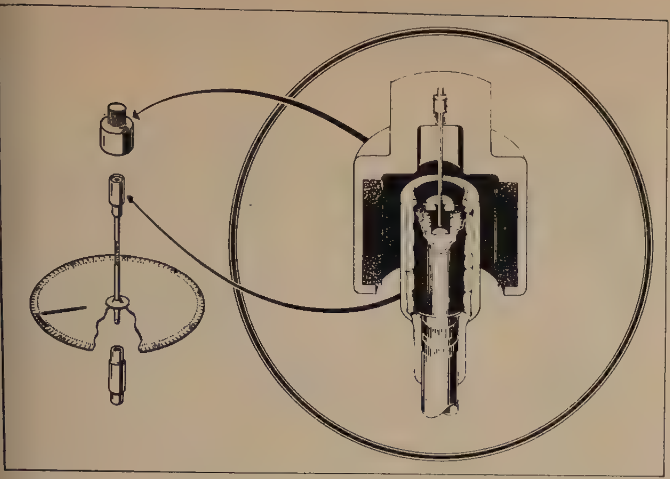
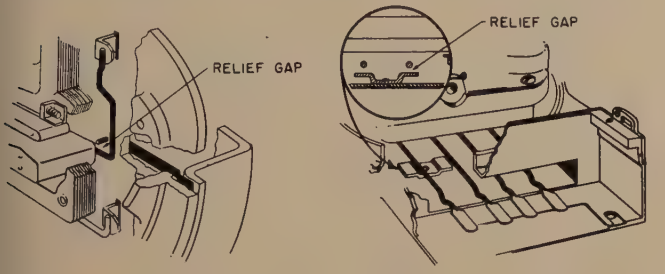


Fig. 6. Magnetic suspension of rotating element of the new single-phase watthour meter. The enlarged section drawing shows the arrangement of the magnetic elements



DETACHABLE "S" TYPE METER FRONT CONNECTED "A" TYPE METER

Fig. 7. Diagrams showing the location of relief gaps in the new types of single-phase watthour meter

value to which it is limited by sparkover of the weakest point of insulation.

To reduce damage to the insulations to a minimum, the location of the sparkover point must be selected and predicted in the design, co-ordinating its impulse sparkover level with those of the other insulations. In the meter described, this has been accomplished by simple means. In the detachable type of meter, brass pins riveted to the meter base provide controlled air gaps to the line leads. As shown in FIG. 7, the pins are riveted through the base to stainless-steel spring clips which contact the lip of the socket when the meter is installed, thus completing the grounding circuit. Similarly, on the bottom-connected type of meter, a formed clip provides the sparkover relief gap from the line leads to ground.

FIG. 8 shows the improvement in appearance and mechanical nicety in the electromagnet design of this meter. Equally real, but not visibly evident, is the improvement in insulation strengths obtained. The current coils consist of round wire preformed to the required shapes. They are assembled onto the current laminations and held in position by means of a special mold. Butyl rubber is then molded and cured around the coils to provide for insulation both between coils and from the coils to the iron, in addition to rigid mechanical positioning. This is in contrast to the usual practice of using taped or enameled-wire coils which also must be separated from each other and from the lamination iron, usually by some form of paper or fiber.

Improved insulating techniques are also evident in the potential coil. Molding of the coil within an enclosure of polyethylene provides a straightforward solution to the difficulties of wrapping and insulating encountered with previous paper-insulated designs. The coil is layer-wound with a thin insulating paper between each layer. The advantages of this construction in providing superior turn-to-turn and layer-to-layer insulation has been proved by many years of satisfactory experience. The enclosure of this coil within the molded polyethylene further improves the design by filling voids with insulating material and reducing the possibility of corona as compared to previous constructions. The result is an increased impulse-insulation level from windings to ground and also between the start and finish terminals of the coil.

The requirement of long life was a major consideration in the choice of these materials for molding the current and potential coils. The improved sealing and omission of material provided by the molding processes materially reduces the effect of high humidity and insures higher insulation levels over a longer life.

The improved insulation strengths obtained permit satisfactory co-ordination of the insulation and the relief gaps. FIG. 9 shows the insulation co-ordination by

(Continued on next page)

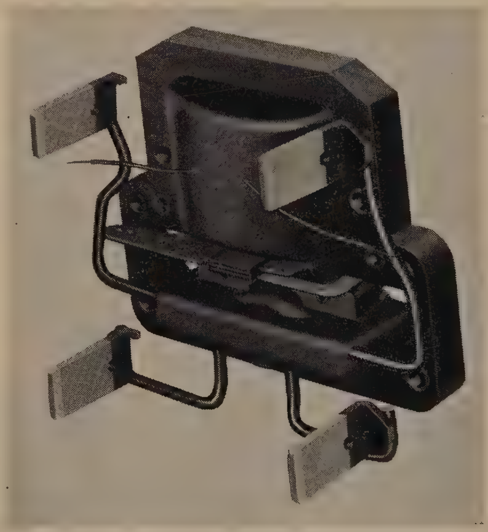


Fig. 8. Electromagnet assembly of the new single-phase watthour meter

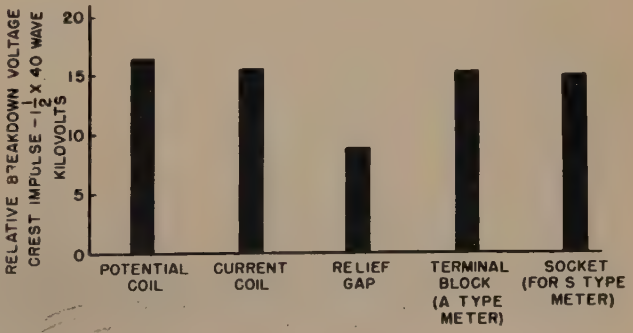


Fig. 9. Relative breakdown voltage of meter components showing co-ordination of insulation levels

SURGE PROTECTION IN WATTHOUR METER

(Continued from preceding page)

comparing relative impulse voltage-breakdown levels of the components of the meter with the relief gaps. The impulse level of the socket used for installing the detachable type of meter is also shown, since it is such an important part of the installation for this type of meter. Variations between individual meters and for different test conditions are to be expected.

SUMMARY

The growing numbers of watthour meters being installed outdoors with the new installation sequence have clearly established the necessity for protection against lightning surge damage. This has been accomplished to a remarkable degree in a completely new meter. Laboratory tests with lightning-type surges show the design to be definitely superior to previous designs.

Effective use has been made of magnetic alloys in combination with the additional protection offered by the conductive sheath enclosing the braking and suspension magnets. The insulation design of the potential and current coils has been improved through use of recently developed materials and methods of construction. Insulation levels have been co-ordinated, so that surge voltages will sparkover at relief gaps which have been incorporated to provide controlled points for sparkover with a minimum hazard of meter damage.

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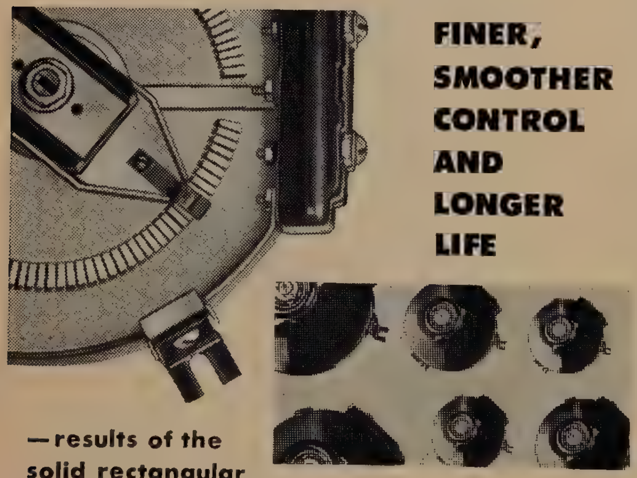

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HIGH LIGHTS AND SIDE LIGHTS

Electric Umpire

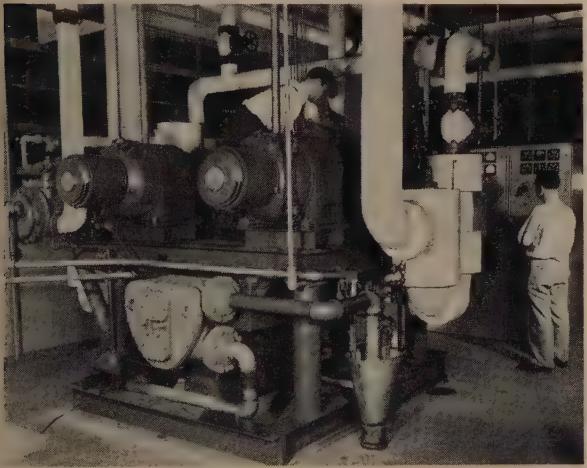
An electric device which specializes in calling bowling fouls will soon be on the market.

A light source and a photoelectric cell are mounted at floor level on opposite sides of the alley at the foul line. Whenever the light is interrupted by a foot slipping across the line, a bell or buzzer sounds and a light indicates the alley in which the foul occurred. An interesting feature of the detector is its ability to "recognize" the bowling ball so that the foul signal is not activated as the ball passes the foul line.

Besides putting an end to arguments among opposing bowlers about whether or not a foul was made, the device may also enable tournament spectators to spot rolls disqualified by fouls.

Educational Unit Power Plants

Engineering students at the University of Nebraska and the University of Maryland soon will use in their studies of power generation and utilization educational unit power plants, which will be used to demonstrate the principles of power generation, control, and associated problems.



A complete small-scale power plant (except for boilers) and a load-absorbing plant aid in teaching the principles of power generation, utilization, control, and associated problems

The apparatus consists of a complete small-scale power plant (except for boilers), and an associated load-absorbing plant. It provides for experiments with automatic extraction, operation from waste-heat boilers, speed regulation, condensing and noncondensing operation, etc

Electrically, students will be able to gain experience in such matters as parallel operation, synchronizing, and variable-power-factor loads and their effect on generation.

The equipment included in each unit power plant consists of two 20-kw turbine-generator sets, piped and valved so that the turbines can run in steam parallel or series; a two-pass surface condenser, condensate pump, and motor steam-jet ejector and after condenser, a 50-hp synchronous motor direct-connected to a 10½-in. Hydrotarder; and generator-, motor-, and turbine-control panels. Valves, piping, wiring, cable, and conduits, as well as a turbine-condenser foundation, are also included.

The turbine-generator sets, with condenser and all associated valves and piping, are shipped as a factory-assembled unit, mounted on a common structural base. Switchgear and control are modern metal-enclosed equipment with complete instrumentation.

Counterstress Gives Straight Welds

The use of counterstress, or prebending, to balance warpage caused by welding has eliminated the need for straightening of welded parts at a middlewestern manufacturing company. Special fixtures have also been designed to make the greater portion of the work flat welding, careful positioning minimizing the necessity for vertical or overhead welds. These features have increased production by expediting the welded construction of the tractors, shovels, front-end loaders, and other road-building and materials-handling equipment produced by the concern.

Welding plays a part so important in the manufacture of this apparatus that almost every component of the machines passes through the welding booth at some time before it reaches the assembly stage. The welded construction must be exceptionally strong because it must withstand heavy-duty work and severe handling in everyday use: loading, hauling, road building, earth moving, and materials handling.

The smallest of the wide variety of parts welded is a ⅜-in. nut which fastens to an accelerator bracket; the largest is the main frame of a giant tractor-loader requiring more than 60 lb of electrode in its construction.

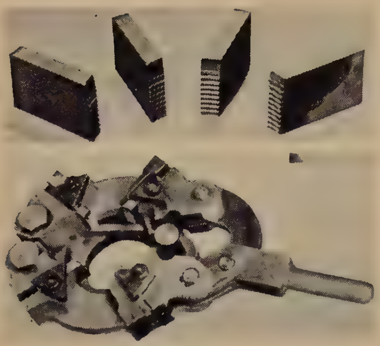
Methuselah among Lamps

Two tiny neon glow lamps, believed to be the world's longest-burning. Requiring only 1/25 watt of electricity apiece, they are used in electrical equipment to indicate that current is on or off. One of these glow lamps will produce a small amount of light for more than 25,000 hours, or nearly three years. The average useful life rating of neon glow lamps, all listed for many years as 3000 hours, has now been increased to from 5000 to 25,000 hours

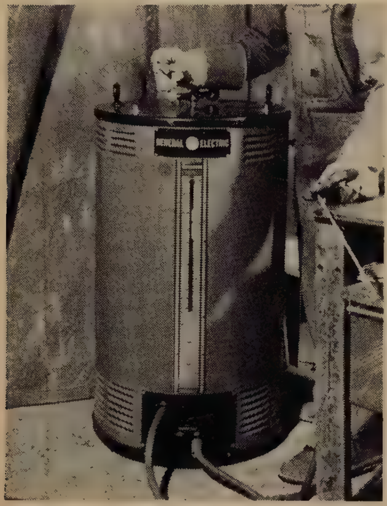
Cold Box for Testing

Engineers in storm suits check a gun turret undergoing test at −65F in the cold box. This is part of new test facilities recently set up for Air Force turrets, where tests for shock and torque are given in conditions simulating those of actual flight

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM



Die Head



Battery Charger

Battery Charger

The sequence charge control is a new device which can be attached to rectifier-type truck-battery chargers to double their working capacity. The device makes it possible to charge two fully discharged batteries in 13 hr from a single rectifier. It utilizes the same automatic two-rate method of charging as that used in standard G-E rectifier chargers.

A high starting rate is applied first to one battery to bring it to within 80 to 90 percent of full charge, and then to the second battery. Both batteries then are automatically given the finishing charge simultaneously. A switch restores the basic characteristics of the original charger so that a single battery can be charged in eight hours. The sequence charge control can be attached to the battery charger unit by a competent electrician in about two hours.—*General Electric Company, Lighting and Rectifier Divisions, Schenectady 5, New York.*

Box Connectors

No. B267 box connectors for armored cable and the No. R267 for loomwire or nonmetallic-sheathed cable provide a simple, fast, positive, and economical method for connecting metallic- or nonmetallic-sheathed cable to device or outlet boxes. One feature of their design is the provision for simultaneous clamping of connector onto cable and into box by merely tightening two screws. Installation is accomplished by hooking bottom tab into knockout, swinging connector to engage rocking clamp, and then tightening. These connectors require no locknuts and accommodate a broad range of cable sizes. They are sturdily built of heavy-gage steel to withstand abuse, are heavily cadmium plated to resist corrosion, and are designed to withstand severe vibration without loosening. Smooth well-rounded wire entryways furnish maximum protection against cable abrasion. Large openings provide for quick, easy, visual inspection.—*Buchanan Electrical Products Corp., 1290 Central Ave., Hillside, N. J.*

Die Head

A new quick-opening die head for threading pipes, bolts, and solid rounds substantially reduces over-all time. This die head has monotype high-speed steel chasers for long-life cutting service, and it can be used on any pipe-threading machine having capacity to 2-in. pipe diameter.

Suitable adaptors are furnished with die heads so that they may be mounted either vertically or horizontally on the machine carriage. Die heads designed for vertical mounting are interchangeable, and likewise those for horizontal mounting. When in place, the die head is quickly opened by means of a hand-operated toggle clamp, permitting rapid removal of stock after threading. Closing the clamp brings the chasers to accurate and positive cutting position. A separate set of chasers is required for each thread pitch and each diameter pipe. Die head adjusting screws permit chaser setting to cut over or undersized threads.—*Peerless Machine Co., 1600 Junction Ave., Racine, Wis.*

Bench Press

A low-cost foot-operated bench press complete with cutting head. This press does a clean cutting job on wire, rod, or sheet metal and it is so designed that the cutting head can be easily removed and any one of seven other special heads quickly inserted. Other available heads perform such operations as indenting, making knock-outs, nibbling, "U-ing," notching, and installing solderless terminals. Blank heads are also available.—*Aircraft-Marine Products, Inc., 1540 North 4th St., Harrisburg, Pa.*

Melting Furnace

A new metal remelter for babbitt, solder, lead, or wax, and insulating compounds. Square in design, requiring less floor space than the conventional round-type furnace, it comes in two standard sizes: No. 2000 with a one-ton capacity metal pot and No. 650 with a 650-lb capacity. Both machines are compact units equipped with hinged cover, ventilating pipe connection, bottom draw-off valve with swing spout, and heating arrangement. They can be equipped for heating by electricity, oil, or any type of gas, as desired. Although regularly furnished for temperatures up to 850, these furnaces can be designed to give any necessary temperature range to meet special requirements. The furnace can be furnished with larger capacity pots in sizes up to five tons.—*Nolan Corp., 1333 East Dominick St., Rome, N. Y.*

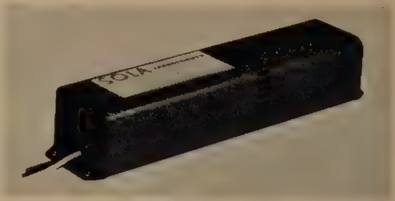
Insulated Wire

The new Turbotherm REL-16A insulated wire, primarily of hookup and lead character, carries 105 C rating, continuous operation for 300 and 600 volts. It comprises a vinyl dielectric with a closely braided lacquered-glass jacket, providing a general-purpose wire, having good electrical, thermal, and physical characteristics. Its operating range of −10 C to 105 C permits the user to have one wire for all hookup and lead applications with resultant economies in engineering, production, and purchasing.—*William Brand & Co., 276 Fourth Ave., New York 10, N. Y.*

Lamp Ballast

A new ballast for the operation of two 75-watt 96-in. Slimline lamps. Protection is provided against fluctuating line voltages by means of the constant-voltage principle.

This ballast unit has the following advantages: small compact size; light weight; low wattage loss; and constant wattage. The pressed-in core-type construction and special care in the impregnation process reduces noise level while the low wattage loss insures cool operation.—*Sola Electric Company, 4633 West 16th Street, Chicago, Ill.*



Lamp Ballast

Bench Press

Melting Furnace

It's as simple as A, B, C.

Where there are no profits, there can be no business. The man who risks his capital in a private enterprise does so for one reason — profits.

The agitator who blasts away at profits is aiming at one target — free enterprise.

Figure it out for yourself.

When your employer's business shows a profit, he can buy more factory equipment.

He can hire more workers to man more machines.

He stays in business, and men stay on their jobs.

But what would happen if there were no profits for anybody?

Sure you know. But let's set it all down.

Businesses would fail.

Factories would close down.

Men would lose their jobs.

Depression would set in.

Breadlines would form.

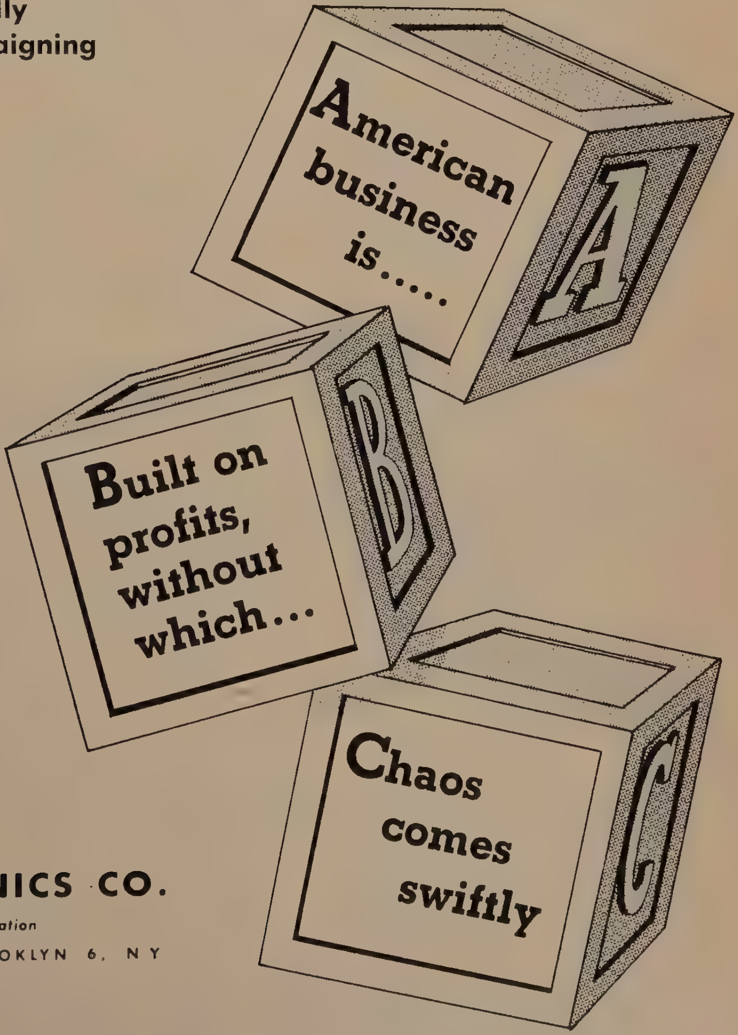
Hunger would feed anger in the hearts of men.

It is then that the agitator would really get his licks in — inciting riots, campaigning for chaos.

His hope is to destroy all the free democratic ways and benefits of our American profit system.

Our hope, yours and mine, is free enterprise . . . and profits. We have but one choice — you and I — to fight for the preservation of the profit system — or to fight each other for food.

It's as simple as that — as simple as A, B, C.



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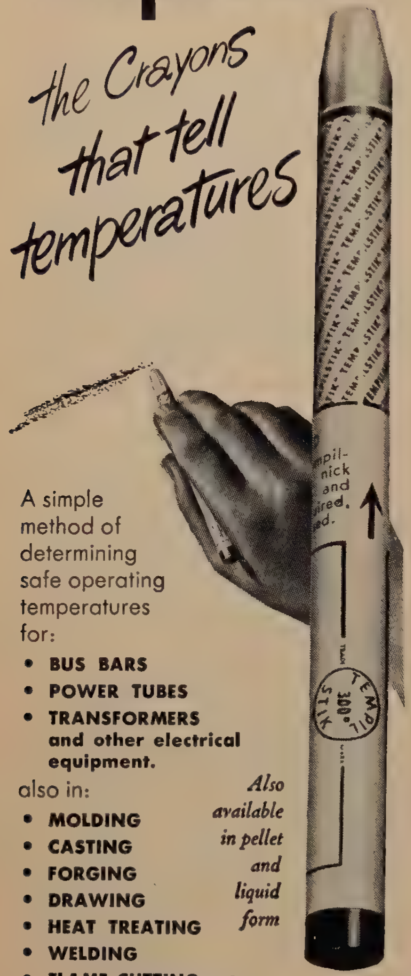
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175	325	700	1300
188	338	750	1350
200	350	800	1400
213	363	850	1450
225	375	900	1500
238	388	950	1550
250	400	1000	1600
263	450	1050	

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TRADE LITERATURE

CAPACITORS—An engineering data folder that condenses all pertinent information on FP and WP capacitors providing easy reference for design engineers. Data on several new types of high-voltage capacitors are included. Four pages.—*P. R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis 6, Ind.*

CONTROL DEVICES—Descriptive and up-to-date technical data given on a complete line of resistors, rheostats, relays, contactors, motor starters, controllers, and accessories. Each section can be located quickly by means of a visual index. Requests for copies must be made on a company letterhead. Two hundred pages. Titled "Electric Control Devices."—*Ward Leonard Co., Mt. Vernon, N. Y.*

DUST CONTROL—The operating principle, various arrangements and capacities, performance characteristics, and engineering data of the Roto-Clone, Type N, hydrostatic precipitator for control of dust generated in manufacturing and process operations are described, and in many instances supplemented by illustrations, dimensional diagrams and charts. Twenty pages.—Bulletin No. 277A.—*American Air Filter Co., Inc., Louisville, Kentucky.*

FLUORESCENT LAMP BALLASTS—Installation, operation, and testing of ballasts for fluorescent lamps are among the topics presented to aid electrical contractors, electricians, maintenance men, and fixture manufacturers. GET-922-B. Twenty pages. —*General Electric Co., Specialty Transformer and Ballast Divs., Fort Wayne, Ind.*

GAGES—Use of the diaphragm-operated multi-pointer gages for measuring pressure, draft, or differential is explained and illustrated. Four styles of casings, all of which are available in sizes to accommodate from one to twelve units, are described. Eight pages. Bulletin No. 163-B—*Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio.*

LINEAR-MOTION BEARINGS—The principle of Ball Bushing operation; the 22 design advantages of this type of bearing; and technical information on seals, lubrication, and installation data are given. Mounting arrangements are suggested, and examples for calculating load capacity and life expectancy are included. Twelve pages.—*Thomson Industries, Inc., Manhasset, N. Y.*

MANOMETER—A presentation of the performance, operation, mechanism and recent improvements in the Type FA-145 precision dial manometer. Specifications and ranges are given. Four pages. Publication No. TP-30-A.—*Wallace & Tierman Products, Inc., Belleville 9, N. J.*

PLASTICS TESTING MACHINES—A presentation of a complete line of equipment for the testing of plastics, including the Plastiversal; Lo-Cap Universal; electronic recorders; and flaw, torsion, stiffness, heat-distortion, creep, and brittleness testers. Illustrations and explanatory charts supplement the text. Bulletin No. 36. Thirty-six pages.—*Tinius Olsen Testing Machine Co., 1036 Easton Rd., Willow Grove, Pa.*

PUNCHING AND NOTCHING—A functionally colored catalog illustrating and describing the Type CJ hole-punching units and Typ HJ notching unit which may be used in combination for punching and notching in the same operation. Sixteen pages.—*Wales-Strippit Corp., 345 Payne Ave., North Tonawanda, N. Y.*

RADIOACTIVITY INSTRUMENTATION—Not only is the wide range of instruments and accessories described but information concerning applications, manufacturing methods, and other pertinent data are also included. Thirty-six pages. Catalog J.—*Nuclear Instrument and Chemical Corp., 223 West Erie St., Chicago 10, Ill.*

SELENIUM RECTIFIERS—The limitations as well as the capabilities of selenium rectifiers are brought out in this booklet designed to aid rectifier users to select, buy, and use them properly. Cell sizes, rating, and grading; construction; coatings and circuits; efficiency; and operation are some of the topics covered. Bulletin RDP-112. Sixteen pages.—*Fansteel Metallurgical Corp., Rectifier Div., North Chicago, Ill.*

STEEL—A manual presenting the various aspects of light-gage steel design for use by architects, designers, and structural engineers. Design charts and tables of structural properties are included. Price $1. Seventy-eight pages. Titled "Light Gage Steel Design Manual."—*American Iron and Steel Institute, 350 Fifth Ave., New York 1, N. Y.*

SWITCHES—General information is embodied on the characteristics of standard and special switches used in broadcast and communications, industrial fields, and in laboratory tests. Four pages. Titled "Switches by Daven."—*Daven Co., Newark, N. J.*

TRUCKS AND TRACTORS—Twenty different models of electric industrial trucks and tractors are illustrated. A questionnaire is included for determining the correct type and model of truck to use under various operating conditions. Four pages.—*Crescent Truck Co., Lebanon, Pa.*

TUBINGS AND SLEEVINGS—Technical data on three different types of Dieflex varnished tubings and saturated sleevings are presented. Minimum, maximum, and nominal inside diameters; grades and colors; and telescoping data have been compiled in easy-to-read tabular form. Four pages.—*Insulation Manufacturers Corp., 565 W. Washington Blvd., Chicago 6, Ill.*

TURN-RATIO INSTRUMENT—A description of the principle, construction, and method of operation of a new portable direct-reading instrument for measuring turn ratio in power and distribution transformers. Bulletin 55. Eight pages.—*James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pa.*

WELDING—A catalog describing the Cadweld process for electrical connections, a method of welding copper to either steel or copper, in which no outside source of heat is required. The types of welders are shown together with equipment requirements for various connections. Eight pages.—*Electric Railway Improvement Co., 2070 E. 61st Place, Cleveland 3, Ohio.*

SOMETHING BRAND NEW IN HOOK-UP WIRE—

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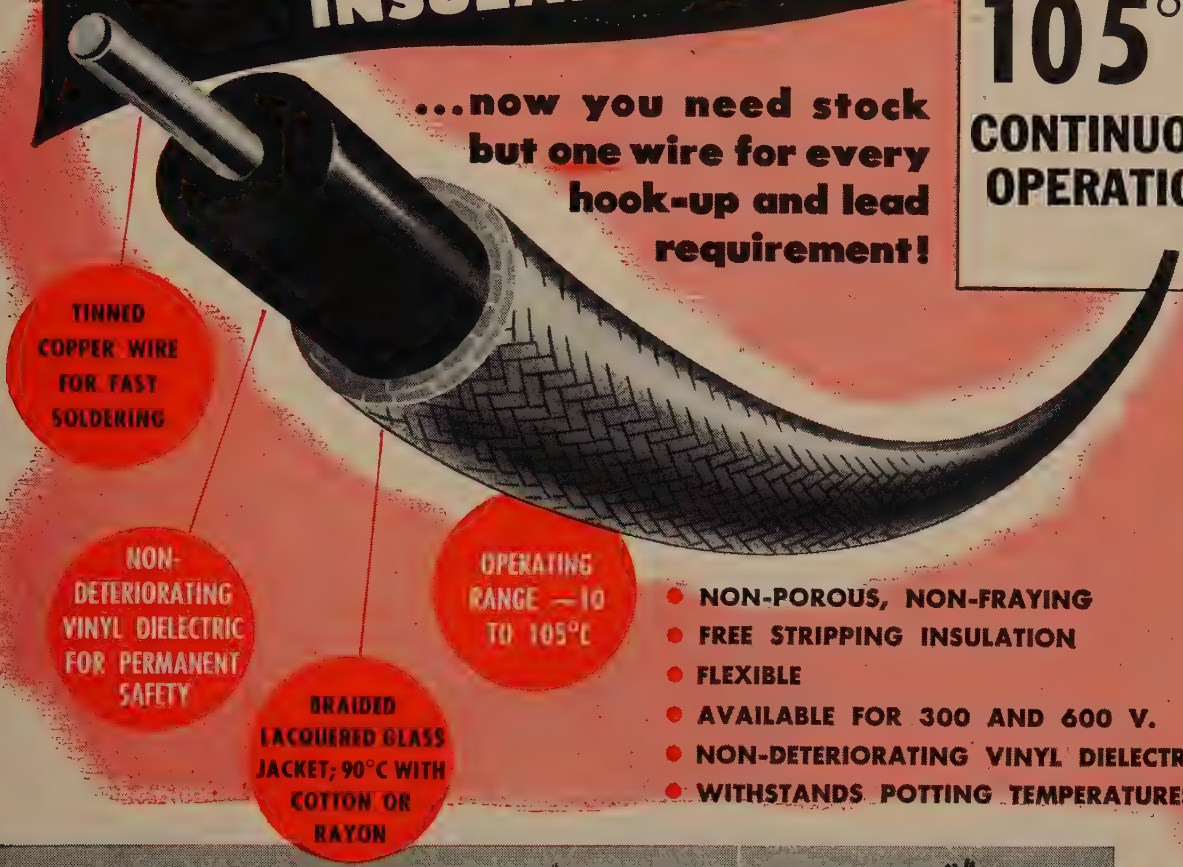
...now you need stock but one wire for every hook-up and lead requirement!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NON-DETERIORATING VINYL DIELECTRIC FOR PERMANENT SAFETY
BRAIDED LACQUERED GLASS JACKET; 90°C WITH COTTON OR RAYON
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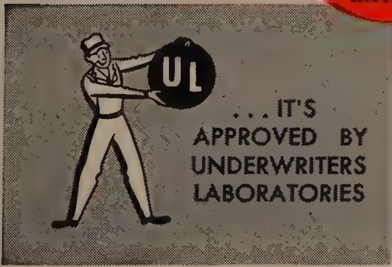
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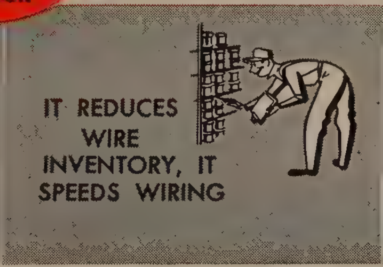
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TURBO REL-16A Insulated Wire is the biggest news in hook-up wire to be announced in recent years. Its unusual characteristics make it possible for the first time, to stock one single type of wire for all requirements—point-to-point wiring, cabling, equipment and component leads.

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The over-all qualities of REL-16A are so thoroughly outstanding that this is the first thermoplastic wire to earn Underwriters' recognition for 105°C continuous operation. Check the advantages; write for free sample today.

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IF IT'S TURBO IT SAFE-GUARDS

BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

HANDBOOK OF INDUSTRIAL ELECTRONIC CIRCUITS

John Markus and Vin Zeluff—McGraw-Hill Book Co., Inc., New York. 1948. xvi + 272 pp. $6.50.

Here is a compilation by two associate editors of the magazine *Electronics* of a large number of electronic-circuit descriptions which have appeared in the technical press over the past decade or so. Although a number of magazines are represented, the majority of the articles come, naturally, from the compilers' publication.

The circuits are grouped logically under such general headings as audio frequency, capacitance control, cathode-ray circuits, etc. The word "industrial" is used in a broad sense. Considerable space is given to communication subjects such as audio-frequency circuits, limiters, and oscillators. Perhaps the most important criticism of the book is the small amount of material presented on such important industrial subjects as motor control, welding control, instrumentation, and power rectifiers.

The circuits selected are those designed for a specific application. Circuit constants have been given in most cases. Hence this book should be especially useful to the electronic handy man or laboratory worker who wishes to put together a circuit to do a given job. To use an architectural analogy, it might be considered a compilation of electronic "house plans" rather than a text on electronic "architecture" or "how to build a house."

The circuits are well drawn, the descriptions are good, and the reference source is given for each circuit.

W. D. COCKRELL

CYBERNETICS, OR CONTROL AND COMMUNICATION IN THE ANIMAL AND THE MACHINE

Norbert Wiener—The Technology Press, John Wiley & Sons, Inc., New York. 1948. 194 pp. $3.00.

Whenever researchers in the physical sciences stumble upon a new tool with which to explore the inorganic world, they hopefully rush to apply the same method of reasoning to lift the veil from some of the mysteries of the organic world. Simultaneously with the growth of the science of energetics and the steam engine a theory of the animal body developed, viewing its various organs as examples of power machinery transforming one form of energy into another. The discovery of the vacuum tube that performs desired operations at low energy levels introduced the science of communication, in which attention is directed not toward the transformation of energy but toward the transfer of information. The present book emphasizes the identity of the process of transmission of messages by means of servomechanisms or by the nervous system. Hunting and muscular tremor, electrical and anatomical shock treatments, the sudden breakdown of an overloaded telephone system and of a worried mentality are all recognized here as manifestations of the same pathological processes.

In the present interlude, while Mars is taking an afternoon nap after a rather heavy lunch, it is inspiring to watch how the resources of statistical mechanics and group theory, feedback circuits and vacuum tubes, the philosophy of Gestalt and Universals are all being put to use in a concerted effort to construct an artificial leg for the lame or to substitute another sense for a lost sense. In effect these pages represent a statement of the present-day status of the age-long efforts of men of good will to correct the malfunctioning of Nature and enable the deaf to hear, the mute to talk, and the blind to see.

Every reader will find numerous passages, and even chapters, that will appeal to his particular type of interest, and also many paragraphs that will arouse his disapproval. Nevertheless, he will consider the time spent in perusing this highly stimulating and provocative book very much worthwhile.

GABRIEL KRON

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NUCLEAR RADIATION PHYSICS

R. E. Lapp and H. L. Andrews—Prentice-Hall, Inc., New York. 1948. xiv + 487 pp. $6.00.

The enormous developments in applied nuclear physics in the past ten years have necessitated training programs for many groups of people who have had only an elementary background in this field. Metallurgists and biologists who use radioactive tracers, engineers who design nuclear power reactors, and the military who handle atomic weapons and worry about situations arising in atomic warfare, all need to know the fundamentals of nuclear physics.

In the past, there has been no book that one could recommend to an audience of doctors, officers, or engineers with the exception of Pollard and Davidson's *Applied Nuclear Physics*. However, that book stops just where the story becomes exciting, with a statement implying that the physicists of 1941 were losing interest in transuranic elements.

Messieurs Lapp and Andrews have filled this gap in the literature by writing this excellent book. The five introductory chapters present a resumé of elementary topics as a basis for what follows. Three chapters on nuclear structure and radiatio are followed by three chapters dealing wi radiation detectors and measuring tec niques. The next four chapters tre nuclear reactions. The latest developmen in accelerators (synchro-cyclotron, synchr tron) are included and the physics of th neutron and of the fission process ar thoroughly treated.

Chapter 16 is unique in being the fir presentation of various types of reactor including power piles and breeders, appear in a book of this level. The fina chapter deals with tracer techniques an health physics, a field that assumes greate proportions every day as more people wor near radiation emitters. Useful data i graphs and tables are exhibited throughou the text and in seven appendices.

The large number of problems and of care fully selected references at the end of eac chapter add to the value of the book.

A number of minor errors should b eliminated in the next printing, which ma be expected soon, as the book undoubtedl will be in great demand. Typical case the direction of propogation in Fig. 2-1 the direction of the arrows in Fig. 15-14 and the calculation of the heat of fission o page 350, maneuvered so as to hit Hender son's value, which is obviously too low.

GERHARD DESSAUE

INSTALLATION AND SERVICING OF LOW POWER PUBLIC-ADDRESS SYSTEMS

John F. Rider—John F. Rider Publishe Inc., New York. 1948. iv + 204 pp. $1.89.

To those interested in the installation an servicing of public-address systems, thi latest book by John F. Rider should be valuable asset. It covers, quite thoroughly all the aspects of the p-a field, from th physical fundamentals involved to the testing of the final installation. Although th title indicates that the book deals primaril with low-power systems, much of the ma terial presented applies equally well t systems of higher power.

Beginning with the fundamentals of sound including human hearing characteristic and a short bibliography of books on soun and acoustics, the book goes on to describ many types of microphones and phono graph pickups. The important subject o impedance matching is covered, as well a amplifier specifications, then loudspeaker their characteristics and methods of in stallation.

Typical installation data are presente for p-a systems in all types of application from small offices or classrooms to armorie and athletic fields. The chapter dealing wit servicing of sound systems emphasizes th use of the oscilloscope in such work.

C. L. HACKLE

TECHNIQUE OF ORGANIC CHEMISTRY, VOL. I

Arnold Weissberger, Editor—Intersciene Publishers, Inc., New York. 1948. ix + 21 pp. $5.00.

This, the second in a projected series o six volumes, covers three ways of accom plishing chemical reactions and thus diffe considerably in subject matter from it predecessor, which dealt with physica methods and was issued in two parts. Bu it retains the character of a laboratory manual in that it describes equipment and technique, and lists references that can be consulted when exhaustive information is needed.

Catalytic Reactions: V. I. Komarewsky and C. H. Riesz

The chemist who wishes to carry out catalytic reactions on a scale not exceeding that of the semipilot plant will find this an extremely well-written manual. Batch and continuous processes at various levels of pressure and temperature are dealt with in detail, much of the dissertation being applicable also outside the field of catalytic reactions. The emphasis throughout is on things that work. Each piece of apparatus has been tried, and experimental data are cited to show what each will do. The illustrations are excellent; for example, many pieces of high-pressure equipment could be constructed directly from the drawings given.

Photochemical Reactions: W. Albert Noyes, Jr., and Virgil Boekelheide

Electrolytic Reactions: Sherlock Swann, Jr.

These two fields are alike in that they have so far found much more limited application than have catalytic reactions. The two chapters describing them, though both well done, consequently tend to be collections of isolated experiments. For example, the halogenation and polymerization of olefins, the carboxylation of hydrocarbons, chlorosulfonations, and addition at a double bond are the principal photochemical processes, while the principal electrolytic reactions are the cathodic reduction of several compounds and the coupling of radicals formed in the anodic oxidation of the salts of carboxylic acids.

Few readers, and no librarians, will be glad to see the designation Volume II on both the book under review and the second part of its predecessor.

NORMAN KIRK
J. R. ELLIOTT

PHOTOELECTRIC CELLS IN INDUSTRY

R. C. Walker—Pitman Publishing Corp., New York. 1948. 520 pp. $8.50.

This book covers the complete range of photoelectric-cell uses in measuring instruments, industrial control, sound reproduction, facsimile, and television. Starting with sections on photoelectric-cell theory, manufacture, characteristics, limitations, and optical systems, the greater part of the book describes the various applications.

The text is very readable and is recommended to laboratory, engineering, and service personnel. The extremely large number of applications is quite inspirational in the variety of ideas presented. There is a large and excellent list of references covering both U.S. and foreign publications. Many references and some statements are a bit out of date. None of the photoelectric developments of the recent war are mentioned. However, these factors detract but little from a fine book.

The notable feature of the book is its well-balanced coverage of a very broad field, wherein each application is described briefly but adequately with words, circuit diagrams, and optical and mechanical sketches. For applications such as sound reproduction, facsimile, and television, other books on the specific subjects give much more information. However, for general coverage as well as for specific information on photoelectric instruments and industrial control, this volume is excellent.

L. U. C. KELLING

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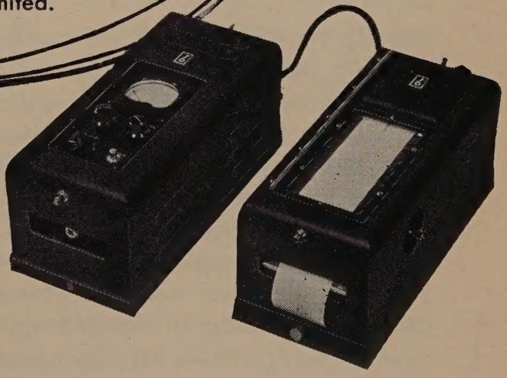

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ELECTRONICS

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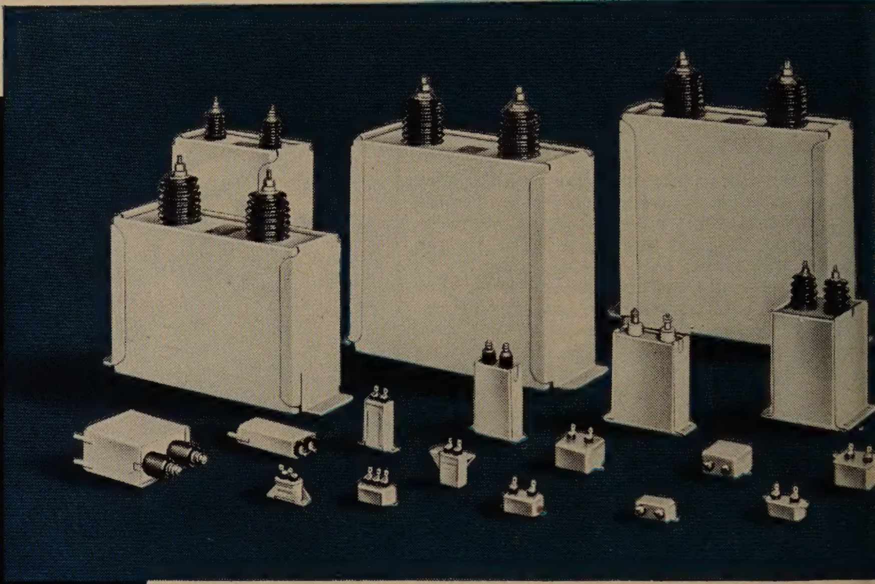


Readily available for DC electronic applications, these capacitors are manufactured in accordance with joint Army-Navy specifications JAN-C-25. Case styles include types CP 53, CP 54, CP 55, CP 61, CP 63, CP 65, CP 67, CP 69 and CP 70. Capacitance ratings are from .01 Muf to 15 Muf, and voltage ratings are listed from 100 to 12,500 volts.

These capacitors are constructed with thin Kraft paper, oil or Pyranol* impregnated, which provides stable characteristics and high dielectric strength. Plates are aluminum foil, manufactured according to detailed specifications. Special bushing construction provides for short internal leads, preventing possible grounds and short circuits. The cases have a permanent hermetic seal to provide longer life. A variety of mounting arrangements are available for various installation requirements. Write for detailed description and operating data: Bulletin GEA-4357A.

*Pyranol is General Electric's non-inflammable liquid dielectric for capacitors.

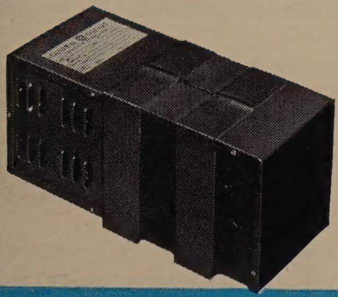
SAVE SPACE CUT COSTS

Less than one inch long, and only one inch square, this postage-stamp-size selenium rectifier offers radio builders substantial savings in production costs. Only two soldering operations and a minimum of hardware are necessary for installation in places where a rectifier tube and socket won't fit. They're built to safely withstand the inverse peak voltages obtained when rectifying (half-wave) 110-125 volts, rms, and feeding a capacitor as required in various radio circuits. Tests prove that selenium rectifiers will outlast the conventional type of rectifier tubes, at the same time costing less. Send for bulletin GEA-5238.

GENERAL ELECTRIC

Digest

TIMELY HIGHLIGHTS ON G-E COMPONENTS

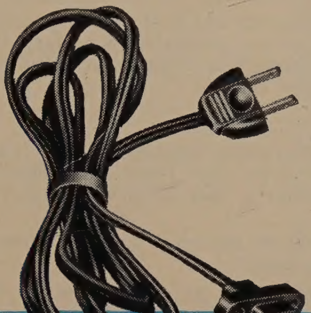


HOLDS OUTPUT VOLTAGE CONSTANT

This 500-va voltage stabilizer is suitable for a wide variety of electronic applications where constant voltage is demanded. Voltage variations from 95 to 130 volts are absorbed almost instantaneously and output voltage maintained at 115 volts (plus or minus 1 percent). There are no moving parts, no adjustments to make. This unit will operate continuously at no load or short circuit without damage to itself. It will limit the short circuit current to approximately twice stabilizer's normal full load current rating. Other sizes available range from 15 to 5000 va. For details, check bulletin GEA-3634B.

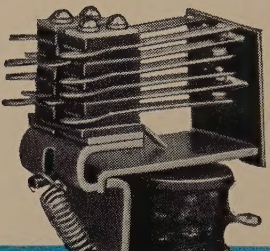
WANT TO TIME TUBE LIFE?

Suitable for installation in radio transmitters, these G-E time meters provide accurate record of tube operating time. They record in hours, tenths of hours, or minutes. Ratings range from 11 to 460 volts. Installation on a panel or switchboard is simplified by quick-wiring leads. Timer harmonizes with other panel instruments in appearance and size. Dependability is assured by Telechron* motor drive. Also available for portable use or conduit and junction box mounting. Check bulletin GEC-472.



FOR YOUR TELEVISION SETS

General Electric's television cord set comes in 6-foot lengths, made of 2/18 Pot-64 brown Flamenol* rip-cord. Set has brown plastic plug and new brown Flamenol connector molded on opposite end. Rip-cord has smooth finish, resists oil, water, acids, alkalies, or sunlight deterioration. Rating is 7 amps., no. 18 wire. Set is designed for assembly on television receiver rear panel, automatically disconnects when panel is removed. Write for further information.



DEPENDABLE CONTROL FOR AUTOMATIC DEVICES

G.E.'s multi-contact relays are inexpensive units built specifically for appliances and vending machines. Construction features assure quiet, reliable operation, and compactness makes them adaptable to a variety of devices such as coin changers, phonographs, and television receivers. Single-circuit contacts or combinations of contacts for multi-circuit application are attached to the same sturdy frame and coil assembly, affording a multiplicity of relay forms. Ratings are 5 amperes at 115 volts or 24 volts, a-c or d-c. Get details from Bulletin GEC-306.

*Trademark Reg. U. S. Pat. Off.

General Electric Company, Section J667-1
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Please send me the following bulletins:

- ☐ **GEA-3634B Voltage Stabilizers**
- ☐ **GEA-4357A D-C Capacitors**
- ☐ **GEA-5238 Selenium Rectifiers**
- ☐ **GEC-306 Multi-contact Relays**
- ☐ **GEC-472 Tube Timers**

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ON ARTICLES IN OTHER TECHNICAL JOURNALS

AVIATION

Arctic Aerial Navigation, by J. M. Christensen. *Mech. Engng.*, Jan. 1949; v. 71, pp. 11–16, 22.

A method for the analysis of complex activities and its application to the job of the arctic aerial navigator.

Psychological Aspects of Stick and Rudder Controls in Aircraft, by Jesse Orlansky. *Aero. Engng. Rev.*, Jan. 1949; v. 8, pp. 22–31.

How airplane control systems may be designed to provide the pilot with optimal sensory information by means of pressure cues obtained from operating the stick and rudder.

BEARINGS

Collisions Through Liquid Layers, by D. Tabor. *Engng.*, Feb. 18, 1949; v. 167, pp. 145–147.

A theoretical study of certain phenomena in metal-to-metal contacts as they occur in lubricated bearings.

BRAZING AND HEAT-TREATING

Current Trends in Good Brazing Practice, by Ralph Melaney and others. *Steel*, Jan. 10, 1949; v. 124, pp. 56–59, 90–91.

Joining similar and dissimilar metals with copper, copper alloys, and silver alloys; includes methods of application, preparation of joint, heating, flux removal and cleaning.

Which Atmosphere for Heat-treating and Brazing? by C. E. Peck. *Am. Mach.*, Jan. 13, 1949; v. 93, pp. 90–94.

The author considers the compositions and characteristics of eight different controlled atmospheres.

ELECTRIC LOCOMOTIVES

What Type Motive Power? by H. E. Dralle. *Ry. Age*, Jan. 1, 1949; v. 126, pp. 4–8.

Surveys the prospects of electric, diesel-electric, and gas-turbine locomotives.

FILMS

Optical Determination of Thin Films on Reflecting Bases in Transparent Environments, by A. B. Kinterbottom. *Optical Soc. of Am. Jour.*, Dec. 1948; v. 38, pp. 1074–1082.

The classical theory of metal and film optics is recapitulated and its implications in connection with various optical methods of studying films and surfaces are indicated.

Optical Properties of Surface Films: II, Alexandre Rothen and Marjorie Hanson. *Rev. of Sci. Instr.*, Jan. 1949; v. 20, pp. 66–72.

Measurements of ellipticity of light reflected from a film-coated metal surface have been made for films varying in thickness from 25 to 40,000A.

GAS AND OIL ENGINES—DIESEL

French Develop Free-piston Engines, by G. Eichelberg. *Power*, Jan. 1949; v. 93, pp. 79–81, 156, 158.

The free-piston power plant considered as a highly supercharged two-cycle diesel engine with expansion extended to atmospheric pressure in a turbine. Report on results attained by Pescara and others.

INSULATORS

Bushings for High Altitude, by F. J. Vogel and H. A. Hart. *Elec. Mfg.*, Jan. 1949; v. 43, pp. 111–113.

By designing high-voltage terminals and bushings for equal corona and breakdown, performance at low pressure can be predicted.

MACHINERY

Protecting Machine Parts With Dust-excluder Boots, by Watson G. Harding. *Prod. Engng.*, Jan. 1949; v. 20, pp. 106–110.

New reinforced synthetic-rubber boots, available in a wide variety of styles, which answer many design problems involving moving machine parts.

Selecting a Material to Do a Job, by D. R. Meier and J. H. Crankshaw. *Foundry*, Jan. 1949; v. 77, pp. 87, 214, 216–218.

Requirements which must be met in the design of any product, as covered in a paper presented before the Malleable Founders' Society.

METAL COATING

Metal Spraying Speeds Many Maintenance Jobs, by John E. Wakefield. *Mill & Factory*, Jan. 1949; v. 44, pp. 147–150.

Methods of spraying, and examples of applications.

Prime Coating Aluminum Sheet, by Clyde St. John. *Iron Age*, Jan. 13, 1949; v. 163, pp. 42–45.

A wash primer, containing a vinyl-butyral resin pigmented with zinc chromate, and the technique used in coating sheet and coils are described.

METALS

Hard-facing Takes to Powder, by Lawrence A. Holtgren and Richard E. Parker. *Weld. Engr.*, Jan. 1949; v. 34, pp. 40–43.

New equipment and techniques for hard-facing such steels as the AISI 400 series.

Inspection With Ultrasonic Waves, by A. E. Rylander. *Tool Engr.*, Jan. 1949; v. 22, pp. 29–32.

Locating internal material flaws or band failures with high-frequency waves.

Stress and Strain States in Elliptical Bulges, by C. C. Chow and others. *Jour. Metals*, Jan. 1949; v. 1, pp. 49–58.

Results of tests on metal sheets restrained at the periphery and subjected to hydraulic pressure.

PHOTOGRAPHY

Spectral Characteristics of Light Sources, by Norman Macbeth and Dorothy Nickerson. *Soc. Motion Pict. Engrs. Jour.*, Feb. 1949; v. 52, pp. 157–183.

A brief description of all the important light sources, with special emphasis on their spectral characteristics and their effect on colored objects.

Xerography: A New Principle of Photography and Graphic Reproduction, by R. M. Schaffert and C. D. Oughton. *Optical Soc. of Am. Jour.*, Dec. 1948; v. 38, pp. 991–998.

A dry electrostatic method for making photographs, reproductions, etc.

REFRIGERATING ENGINEERING

Heat-transfer Rates for Refrigerant Boiling in Horizontal Tube Evaporators, by L. G. Seigel and others. *Heat. Piping & Air Cond.*, Jan. 1949; v. 21, pp. 159–162.

Showing the variations in heat-transfer rate which occur when Freon 12 is boiled inside smooth horizontal tube evaporators.

Pressure Drop With Change of Phase in a Capillary Tube, by Gerald P. Marcy. *Refrig. Engng.*, Jan. 1949; v. 57, pp. 53–57, 86–88.

An original method of computing the length of a capillary tube to be used for the adiabatic expansion of refrigerant.

RESEARCH

New Jersey's Semicircle of Science. *Bus. Week*, Feb. 26, 1949; pp. 30, 32, 34, 36, 39.

A survey of the variegated research activities situated in or near New York City.

STANDARDS—SCREW THREADS

The Sellers, Or Franklin Institute, Standard Screw Thread, by Coleman Sellers, 3rd. *Franklin Inst. Jour.*, Feb. 1949; v. 247, pp. 95–99.

The history of early attempts to standardize screw threads, with special attention to the contributions of William Sellers and the Franklin Institute.

Unified Screw-thread Standards. *Mach. Design*, Jan. 1949; v. 21, pp. 127–128, 182.

How unified standards will differ from the present national standard, and the principles which will govern the establishment of new allowances and tolerances for the various grades.

STEEL

Heat-treatment of Tool and Die Steels, by Peter Payson. *Mach.*, Jan. 1949; v. 55, pp. 162–166.

The first in a series of three articles describes the heating cycles for five typical tool steels and results obtained.

Use of Hardness Data Restricted, by A. R. Troiano. *Steel*, Jan. 17, 1949; v. 124, pp. 66–71.

Limitations of the end-quenched hardenability test as a means of comparing various steels are described.

THERMOMETERS AND THERMOMETRY

Methods of Minimizing Errors in the Measurement of High Temperatures in Gases, by E. Marston Moffatt. *Instruments*, Feb. 1949; v. 22, pp. 122–132.

The theory and methods of measuring the temperature of a flowing gas stream.

VACUA

Conductance of Bends and Concentric Tubes of a Vacuum System, by E. V. Sherriff. *Jour. Sci. Instr.*, Feb. 1949; v. 26, pp. 43–45.

Measurement of conductances in a vacuum system of right-angle bends and manifolds constructed of two concentric tubes.